# FINAL REPORT 2021

## INVENTORY OF NORDIC COMPETENCE AND CAPABILITY FOR CLEANING-UP ON-SHORE OIL SPILLS AND REMEDIATING OIL CONTAMINATED SITES FOR THE RUSSIAN BARENTS REGION

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# ABBREVIATIONS

| | |
|---|---|
| AS | Air Sparging |
| BAT | Best Available Technologies |
| BEP | Best Environmental Practices |
| BHSF | Barents Hot Spots Facility |
| BTEX | Benzene, Toluene, Ethylbenzene, Xylenes |
| CBC | Cross Border Cooperation |
| ECRT | Electrochemical Remediation Technologies |
| EDD | Environmental Due Diligence |
| EEA | European Environmental Agency |
| EIA | Environmental Impact Assessment |
| ESA | Environmental Site Assessment |
| ERA | Environmental Risk Assessment |
| GEF | Global Environmental Facilities |
| GOST | National Standard |
| HEGs | Regional Hotspot Exclusion Groups |
| HS | Hot Spot |
| ISCO | Chemical Oxidation |
| ISTR | In Situ Thermal Remediation |
| MNA | Monitored Natural Attenuation |
| MNRE | Ministry of Natural Resources and Environment |
| MPE | Multi-Phase Extraction |
| NEFCO | Nordic Environment Finance Corporation |
| NPAF | National Pollution Abatement Facilities |
| O&M | Operation and Maintenance |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PCB | Polychlorinated Biphenyls |
| PHC | Petroleum Hydrocarbons |
| POPs | Persistent Organic Pollutants |
| RF | Russian Federation |
| SHE | Subgroup on Hot Spots Exclusion |
| SVE | Soil Vapour Extraction |
| TF CS | Task Force on Contaminated Sites |
| TPE | Multi-Phase Extraction |
| ToR | Terms of Reference |
| UNEP | United Nations Environment Programme |
| USEPA | Environmental Protection Agency of the United States |

# SUMMARY

Contaminated soil management and remediation of environmental damage has been a problem in Russia for many years and due to limited or no actions, and continuous accumulation has become very acute. There is no region in Russia the environment of which has not been damaged. The areas most susceptible to environmental damage today are the territories near settlements and industrial lands. The environmental hazard grows each year. Therefore, it is urgent that clean-up of the environmental accumulated damage is addressed as soon as possible.

The Assignment full title is Inventory of Nordic Competence and Capability for Cleaning-up On-Shore Oil Spills and Remediating Oil Contaminated Sites for the Russian Barents Region. The project is funded from the Barents Hot Spots Facility that is administered by Nordic Environment Finance Corporation (NEFCO) and aimed at solving the environmental issues in the hot spots (HS) of the Russian sector of the Barents Region. The major task of the Facility is to provide grants for financing the technical assistance, mainly pre-feasibility study, business and financial plans or environmental impact assessments.

As commissioned by NEFCO the Consultant has conducted a study aimed at inventory of relevant Nordic competence and capability for cleaning-up on-shore oil spills and remediating oil contaminated sites, evaluation of relevant applicable remediation technologies, and Nordic companies and institutions dealing with soil pollution issues.

The main objective of the Assignment is to invite and engage Nordic companies and institutions with key competencies, and especially related to relevant oil remediation technologies, to contribute to the cleaning-up of on-shore oil pollution in the Russian Barents region, that contribute to the final elimination of hot spots from the hot spots list.

The study has been based on a combination of data collection, analytical analysis of gathered information from printed and internet sources on implemented and ongoing activities related to management and remediation of contaminated soil, and in particular oil-polluted soil, in the Nordic countries and the Russia Barents region, as well as consultations with stakeholders in the Barents region. To ensure that more practical and realistic analysis and recommendations are generated by the Consultant, additional consultations were arranged with NEFCO, Task Force on Contaminated Sites, International Barents Secretariat, Regional Hotspot Exclusion Groups (HEGs) and other stakeholders addressing oil pollution and contaminated site issues.

This Report presents results of the conducted study, as well as recommendations and proposals on how to engage key Nordic competencies to contribute in improving the environmental status of the oil related hot spots in the Russian Barents region.

The structure of the Report was developed according to the requirements of the Terms of Reference (ToR). **Chapter 1** is a description of collected data and available information, guidelines, recommendations, conducted studies, and project materials related to oil pollution issues in the Barents Region. **Chapter 2** describes soil remediation technologies, which are widely used for remediation of contaminated land including the Nordic countries, with particular focus on technologies for oil pollution remediation. **Chapter 3** contains an overview of companies and institutions from the Nordic countries: Sweden, Finland, Norway and Denmark dealing with soil contamination and oil pollution issues. **Chapter 4** describes similar issues addressing soil contamination and oil pollution in Russia. Analysis of identified Nordic competence and technologies relevant for implementation in North-West Russia is presented in **Chapter 5**. **Chapter 6** provides short analysis of barriers for Nordic companies in entering to the Russian Arctic and Barents region. **Chapter 7** presents conclusions and recommendations for further actions to contribute to cleaning-up of oil pollution in the Russian Barents region.

Apart from the information in the relevant chapters, the Report contains additional information that allows getting a more complete picture of the existing aspects and possibilities of engaging Nordic companies and authorities to contribute to the Russian sector's development.

# 1. COLLECTION AND ANALYSIS OF AVAILABLE INFORMATION

This chapter includes analysis of the available information, guidelines, recommendations, conducted studies, and project materials related to oil pollution issues within the scope of the Barents Environmental Hot Spot and the Task Force on Contaminated Sites (TF CS).

For this purpose, the Consultant collected and studied data from open printed and Internet sources on implemented and ongoing activities related to oil polluted land and site remediation in the Barents and Arctic regions, as well as Nordic experience in this field. In addition, the relevant Barents and Nordic bodies[1] were contacted to collected more information and to get more complete picture of the implemented and on-going activities addressing oil polluted site management and remediation.

In recent years, issues of soil contamination have a high priority worldwide. Therefore, oil-related pollution issues have become increasingly relevant in the Barents and Arctic regions. Despite active efforts and a significant amount of work on oil polluted land management and remediation, carried out in Nordic and European countries, information about such activities is not widely disseminated in open sources by involved stakeholders, and the one, that is posted, is rather scattered.

The analysis shows that measures related to soil contamination were of high priority within Barents region and Nordic countries' policies. Nevertheless, the international activities in the Barents region was focused more on the issues addressing offshore oil spills. However, issues related to on-shore oil pollution were not left without attention and a number of activities were implemented in the Barents Euro-Arctic region to reduce negative environmental impact from oil polluted land.

Some examples of joint international activities related to soil contamination and oil pollution, implemented in Barents, Arctic and Nordic regions, are listed below:

- "An Inventory of Nordic Waste Management Enterprises" for the implementation of the Waste Management Plan of the Murmansk Oblast (basically operators, but also suppliers of equipment), 2007, Murmansk region, NEFCO
- Inventory and Preparation of Nordic Suppliers for Waste Management in Murmansk Oblast, 2007, Murmansk region, NEFCO
- Demo-project on Restoration of the Environment in the Area of a Decommissioned Military Facility near the Village Pokrovskoe, Onega District, Arkhangelsk Region, 2010, UNEP/GEF, NPAF (National Pollution Abatement Facilities, Russian Federation )
- Pre-investment Study on Oil waste management program of the Murmansk region, 2010, UNEP/GEF, NPAF, NEFCO
- "Pilot Project: Improvement of the Emergency Oil Spill Response System Under the Arctic Conditions for Protection of Sensitive Coastal Areas (Case Study: The Barents and the White Seas)", 2010, UNEP/GEF, NPAF, NEFCO
- Pre-investment Study on Land Remediation from Oil Products in Water Protected Area of the Northern Dvina River of the White Sea Basin, Near the Settlement Krasnoe of Primorsky District, 2010, UNEP/GEF, NPAF
- Survey and Preparation of Proposals for the Remediation of Franz Josef Land, 2010, UNEP/GEF, NPAF
- Remediation of Oil Pollution in Mezen City of Arkhangelsk Region, Phase 1: Preliminary Environmental Site Assessment (ESA), 2010, NEFCO and Barents Secretariat in Kirkenes

[1] NEFCO, IBS, Nordic Council of Ministers, Nordic networks for contaminated soil, regional HRGs (Murmansk and Arkhangelsk regions, Nenets Autonomous Okrug, Republic of Komi and Republic of Karelia), TF CS members.

- Land Remediation from Oil Products near the Settlement Krasnoe of the Primorsky District of the Arkhangelsk Region, Phase 1: ESA, 2011, NEFCO
- Mapping of Oil-polluted Lands in Arkhangelsk Region. Pre-feasibility Study, 2011, NEFCO
- Concept Study for Remediation of Oil Wells at the Voivozhskoye Oil Field, Komi Republic, 2011, NEFCO
- “Pre-Project Study on Wood Waste Landfills in the Urban Settlement of Verkhnetulomsky, Murmansk Region” for getting an expert opinion on the environmental impact, possible technical solutions, financial estimates of possible investment project, 2014, Murmansk region, NEFCO
- A study of Best Waste Management Practices for Small and Remote Arctic Communities (in Alaska, Canada, and Finland), 2018, Arctic Council
- Arctic Coast Bioremediation (ACBR) aims at developing an innovative tool for combating the adverse effects of pollution – a biotechnology for comprehensive remediation of oil contaminated marine coastal areas in the Arctic, which will be a more efficient and eco-friendly solution in comparison with the existing methods, 2018-2021, Finland, Norway and Russia, Kolarctic CBC 2014-2020 Programme
- SA2 "Contaminated Sites Management-Related Training for Decision-Makers and Practitioners of the Barents region", 2020-2021, NEFCO, Subgroup on Hot Spots Exclusion (SHE)
- Guidelines on Best Environmental Practices on Contaminated Sites Investigation and Management for the Russian Barents region (under planning), NEFCO, SHE

Soil contamination is of particular interest in most societies since it does not only affect the environment but humans inclusive. When soil is contaminated, in most cases it stops being ideal for purposes of agriculture, recreation and other industrial activities. In the soil, pollutants usually stay for longer periods compared with other media such as air and water.

During last 20-30 years, Nordic and European countries have obtained a wide experience in management and remediation of contaminated sites, including oil polluted land. The Nordic countries have national legislation and regulatory frameworks (or in some cases regional) to deal with local soil contamination. Finland, Norway, Denmark have central national data inventories, while Sweden manages their inventories at the regional level. The Nordic countries (authorities and companies) had acquired wide competence and skills in management and control of soil contamination: site identification, preliminary investigations, main site investigations, implementation of risk reduction measures, and monitoring systems. They are far advanced in the research and implementation of modern in situ and ex situ remediation techniques for contaminated soil and constantly continue to investigate new opportunities and applicability of the remediation techniques. Some European countries have funding mechanisms for abandoned contaminated sites (sites where no liable party can be identified) at national or regional level.

The data, approaches, methods, and techniques obtained from various Nordic and Russian best practices should be collected and published in a form available for everyone. It will allow increasing knowledge of relevant stakeholders on both workable, more challenging and unworkable practices and would encourage the use of modern approaches and techniques in project work at all levels (national, regional and local).

# 2. NORDIC REMEDIATION COMPETENCE AND TECHNOLOGIES

Actions to remediate a site is taken when a pollution poses a risk to human health or the environment, or if there is a need to develop a polluted site, e.g. from a brownfield site to residential area. The best available remediation technology differs from case to case, based on the type of pollutants, depth of pollution and site-specific conditions such as type of soil, buildings on site, infrastructure, and climate. The choice of best available technology is based on knowledge of the technologies as well as knowledge of the given pollution. Knowledge of the pollution is based on site investigations to determine the quantity, quality and location of pollution, as well as environmental risk assessment to quantify the risks for human health and the environment, often including acceptable (clean-up) criteria for remediation.

This chapter presents overview of remediation technologies, which are widely used for remediation of contaminated land, including Nordic countries. Presented information describes remediation technologies for all types of contaminated sites in general and with particular focus on technologies for oil pollution remediation. Selection of a technology depends on the specific contaminants and concentration, as well as site-specific conditions such as contaminant depth and volume, soil texture, infrastructure and environmental goals for the site. Sometimes, a combination of different remediation technologies are used to obtain greater efficiency.

## 2.1 REMEDIATION TECHNOLOGIES FOR CONTAMINATED SOIL

Up to the present, the most common remediation technology has been the excavation of contaminated soil and its disposal at landfill (sometimes referred to as ‘dig and dump’). However, increasing regulatory control of landfill operations and associated rising costs, combined with the development of improved *ex situ* and *in situ* remediation techniques, is expected to alter the pattern of remediation practices[2]. Development and use of remediation technologies have progressed and a large number of clean-up alternatives have evolved and improved over the past two decades.

Soil remediation is either done without disturbance to the soil (in situ) or by excavation and subsequent treatment/disposal (ex situ):

***Ex situ*** – a method for soil and groundwater decontamination where the contaminated matrix is removed from its natural environment and is treated either on the original site or transported off site for treatment or to landfill.

*(+)* Ex situ remediation is fast, predictable and efficient way for soil decontamination because of the ability to homogenize, screen, and continuously mix the soil. In some cases, it is the most cost-efficient method available.

*(-)* Despite these advantages, ex situ remediation causes disturbance to the soil and requires replacement of the removed soil with a clean soil. For larger pollutions, it may also lead to higher costs than in situ alternatives. The use of heavy machinery and transport over long distances causes climate gas emissions and changes to the landscape and ecosystem. Effects of climate gas emissions have not been included in assessment of remediation options thus far, but will likely become an important issue for decision-making in the future.

***In situ*** – a method for soil and groundwater decontamination where the contaminated matrix is treated in situ, in its original place, without any displacement.

[2] https://www.eea.europa.eu/data-and-maps/indicators/progress-in-management-of-contaminated-sites-3/assessment/view

*(+)* In situ remediation is applied in a natural, heterogeneous and less controlled environment. For larger pollutions, in situ technologies are often the more cost-effective options, they avoid increased dispersion of pollution and climate gas emission due to excavation and transport. Soil remediation using completely or partly in situ methods would reduce hazardous environmental effects.

*(-)* However, in situ treatment typically require longer treatment time, the uniformity of the treatment effectiveness in soil might be uncertain and the monitoring of the remediation progress might be difficult. Remediation time is especially crucial for sites with development deadlines, e.g. construction of buildings, roads etc.

Some technologies can have both in situ and ex situ applications. While the principle of the technique remains the same, the practical set-up differs. Remediation methods can be based on biological, physical or chemical contaminant removal. Biological remediation is based on using microorganisms, fungi and plants to degrade or immobilize pollution. This can be done by either adding microorganisms/fungi or planting plants, or by adding nutrients to enhance the microbial fauna that degrades or immobilizes the given pollution. Physical methods are based on mechanical actions to remove the pollution, e.g. by excavation, flushing the soil or thermo treatment. Chemical methods are based on the addition of chemicals to enhance degradation/immobilization or enhancement of reactions to degrade pollution. Table 1 presents description of well-established and most used in situ and ex situ remediation techniques.

**Table 1. Description of various in situ and ex situ remediation techniques including some of their benefits and disadvantages**

| METHODS | | PRINCIPLE | BENEFITS | DISADVANTAGES |
|---|---|---|---|---|
| ***IN SITU*** | | | | |
| **Biological** | Monitored Natural Attenuation (MNA) | Exploits natural (biological, physical and chemical) processes to reduce the concentration, mobility and/or toxicity of a contaminant, efficiency of soil cleanup and risk reduction are monitored.<br>Exploits the indigenous microbial population to degrade or transform dissolved or residual contaminants within the soil's saturated zone. | - cost-effective<br>- no new waste or discharge are created | - long-term process<br>- long-term monitoring required<br>- only suitable if pollution does not pose a risk to human health or the environment<br>- not suitable for heavy metal remediation<br>- conceptual model of the site required |
| | Biostimulation | Stimulates the natural microbial contaminant degradation by addition of nutrients, oxygen or carbon. | - cost-effective<br>- well-known method | - only suitable for degradable contaminants<br>- low contaminant bioavailability reduces degradation efficiency |
| | Bioventing | Stimulates natural microorganisms to biodegrade organic constituents adsorbed on soils in the unsaturated zone, soil by inducing air or oxygen flow into the unsaturated zone and, if necessary, by adding nutrients. | - well-known method | - unstable in high soil moisture or low permeability soils |
| | Bioaugmentation | Adding indigenous or exogenous (non-indigenous) microorganisms to enhance or supersede the existing microbial population (degrade contaminants, reduce their mobility and/or their toxicity). | - minimal site disturbance<br>- successfully used<br>- can be targeted for all contaminants (degradation or immobilization) | - using non-native microorganisms is controversial |
| | Air Sparging (AS)<br>- Cometabolic AS,<br>- Bio-Sparge,<br>- C-Sparge | Injection of air/oxygen directly into groundwater and soil to volatilize contaminants. Volatilized contaminants can be removed by vacuum suction.<br>Enhances biodegradation of contaminants in and above the water table, as it acts as a nutrient for bacteria. | - minimal site disturbance,<br>- well-known method,<br>- efficient in homogeneous soil with high permeability | - unstable in low permeable or heterogeneous soils<br>- possible uncontrolled movement of potentially dangerous vapors<br>- only suitable for volatile or easily degradable organic contaminants |
| | Organic Liquid Nutrient Injection | Enhancing anaerobic bioremediation by adding organic liquids (lactate, molasses, Hydrogen Release Compound (HRCÂ), and vegetable oils) resulting in the generation of hydrogen. | - successfully used | - introducing cold water or gas may slow the remediation process<br>- only suitable for volatile or easily degradable organic contaminants |
| | Nitrate Enhancement | Introducing solution of nitrate to groundwater to enhance anaerobic biodegradation. | - successfully used | - is of concern because nitrate is a regulated compound |
| | Phytoremediation | Use of living plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. | - low-cost,<br>- sustainable method,<br>- a broad technology type | - long treatment time (years, decades),<br>- requires considerable space |
| **Chemical** | Chemical oxidation (ISCO) | Injection of chemical oxidants (peroxide, ozone, and permanganate) into soil to cause a complete or partial degradation of contaminant. | - relatively fast<br>- rapid degradation also in high contaminant concentrations | - nonselective degradation can cause negative environmental impacts |

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| | | | - effective for large areas | |
| | Oxidation with Hydrogen Peroxide | Injection of liquid hydrogen peroxide into a contaminated soil and/or aquifer in order to convert contaminants into non-toxic compounds, mainly water vapor and carbon dioxide. | - short time<br>- successfully used | - unstable in low permeable or heterogeneous soils<br>- most efficient with pH from 2 to 5 |
| | Chemical Solidification/ Stabilization (S/S) | Introducing chemical reagents - thermoplastic polymers (asphalt bitumen, paraffin, polyethylene), thermosetting polymers (vinyl ester monomers, urea formaldehyde, epoxy polymers), and other proprietary additives to contaminated soil to limit the wastes solubility and mobility, or to lower their toxicity. | - apply to many contaminants, including all classes of radioactive waste, organics, inorganics, heavy metals, and mixed waste | - the depth of contaminants may limit some types of application<br>- reagent delivery and effective mixing are difficult |
| **Physical** | Soil vapor extraction (SVE) | Applying a high vacuum to the soil to induce air flow and remove volatile contaminants.<br>Applies light to medium petroleum hydrocarbons such as gasoline, diesel, heating oil, and kerosene. | - cost-effective,<br>- well-known method | - low efficiency in wet and dense soil<br>- effective within the vadose zone<br>- complimentary technologies required |
| | Soil flushing | Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the ground water to raise the water table into the contaminated soil zone. Contaminants are leached into the ground water, which is then extracted and treated. | - cost-effective | - effectiveness depends on soil hydro-geologic variables and contaminant type,<br>- not efficient in low permeability soils (clays),<br>- recovered groundwater may need treatment |
| | Electrokinetic Remediation<br>- Electroosmosis,<br>- Electromigration<br>- Electrophoresis | Inducing an electric field of low density into the soil to cause movement and desorption of charged contaminants, and stimulates degradation of organic contaminants.<br>Intends to separate and extract radionuclides, heavy metals and organic contaminants from saturated or unsaturated soils, sludges, sediments and groundwater. | - suitable for low-permeability soil (clays and silt)<br>- suitable for saturated or partially saturated areas in the soil matrix | - could prove to be a time-consuming process<br>- acidification of soil can lead to leaching of metals<br>- may require installation of additional technology |
| | Electrochemical Remediation Technologies (ECRTs) | Use a proprietary AC/DC electrical signal to mineralize organic compounds, polarizes the soil or sediment (soil), causing soil particles to charge and discharge electricity, cause redox reactions in all interfaces within the soil–groundwater–contaminant–electrode system, mineralizing organics and increasing the mobilization of metals. | - relatively low energy input<br>- effective within months,<br>- metals generally migrate to and deposit at both electrodes | - remediate faster in clays and silts than in sands and gravels,<br>- working depth is limited by the availability of drilling technology |
| | - Solidification / Stabilisation (S/S)<br>- Encapsulation | Reduction of contaminant mobility and accessibility by coating the soil or via reaction with binding reagent (cement, fly ash, lime, polymers),<br>The most common form of S/S is a cement process.<br>Polyethylene Encapsulation of Radionuclides and Heavy Metals (PERM) process encapsulates contaminants in polyethylene. | - relatively fast,<br>- applicable to contamination within the saturated and vadose zones<br>- well-known method, used for sediment in Norway and Finland | - dewatering might be required to allow proper soil mixing below water table level<br>- easier to implement in sandy, silty or gravely soils |
| | Multi-phase extraction (MPE) | Uses a high-vacuum system to remove both contaminated groundwater and soil vapor. In MPE systems a high-vacuum extraction well is installed in the zone of contaminated soils and groundwater. Fluid/vapor extraction systems | - provides both remediation and exposure mitigation | - effectiveness depends on site geology and contaminant characteristics<br>- requires both water treatment and vapor treatment |

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| | | depress the water table and water flows faster to the extraction well. MPE removes contaminants from above and below the water table. | - can result in complete removal of the source of the impacts | - complementary technologies maybe required |
| | Two-phase extraction (TPE) | Similar to MPE, but soil gas and liquid are conveyed from the extraction well to the surface in the same conduit, but not in separate conduits by separate pumps or blowers like in MPE system. | | - requires an oil/water separator |
| | Hydraulic containment | To control the migration of dissolved contaminants - using of pumping wells to change the hydraulic gradient and the excavation of trenches or installation of drains to intercept the contaminant plume. | - allows for the recovery of a wide range of dissolved contaminants<br>- well known method | - not suitable for all aquifers |
| **Thermal** | In situ thermal remediation (ISTR) | Consists of heating subsurface groundwater and the vadose zone to facilitate volatilization or other contaminant removal mechanisms, followed by contaminant extraction and treatment. | - well-known method for organic pollutants<br>- targets more pollutants than air sparging due to operation at higher temperatures | - only suitable for volatile and degradable organic contaminants at the treatment temperatures<br>- in Arctic environments, potential impact on permafrost |
| ***EX SITU*** | | | | |
| **Physical** | Excavation and off-site disposal | Removal and transportation of soil elsewhere for treatment or landfill use. | - fast and effective | - resource consuming<br>- cause environmental effects |
| | Complex sorting | Excavating and processing of soils and wastes into multiple waste streams prior to reuse, recycling and reprocessing. | - fast and effective<br>- allows for sustainable soil remediation<br>- obtaining of benefit of reusing | - resource consuming |
| | Incineration | Destruction of contaminants using high temperatures (800-1300°C) to volatilize and combust hazardous waste. | - removal efficiency 100%<br>-targets many organic pollutants, including POPs | - expensive<br>- high energy use |
| | Thermal desorption | Use of heat (90-560°C) to separate contaminant from soil by volatilization, followed by destruction of contaminants from vapors. | - potential for high contaminant removals | - might need pretreatment of soil (dewatering, screening)<br>- treatment and control of air emissions required |
| **Biological** | Composting<br>- Aerobic pile<br>- Bioreactor<br>- Windrow composting | Organic wastes are degraded by microorganisms at elevated temperatures under both aerobic and anaerobic conditions. Soils are excavated and mixed with bulking agents and organic amendments, such as wood chips and plant wastes that enhance porosity. | - cost effective<br>- well-known method | - requires substantial space<br>- suitable only for some organic contaminants<br>- heavy metals are not treated |
| | Aerobic bio-pile | Excavated soils are mixed with soil amendments, formed into compost piles, and enclosed for treatment. After remediation the excavated material is either returned to its original location or disposed | - relatively fast<br>- cost effective | - soil excavating<br>- pretesting is required to identify the best amendments<br>- large area for the system construction required |

| | | | | |
|---|---|---|---|---|
| | Bioreactor | Treating the soil/compost in enclosed reaction vessels by mechanical agitation and aeration to optimize the biodegradation process and reduce treatment time. | - easy to control due to enclosed system | - not suitable for inorganic contaminants |
| | Windrow composting | Large rocks and debris are removed from excavated soil and amendments (such as straw, alfalfa, manure and agricultural wastes) are added. The material is layered into long piles, known as windrows and are thoroughly mixed by turning with a commercially available composting machine. | - the most cost-effective composting alternative | - has the highest fugitive dust emissions (i.e., windblown dust and particulates)<br>- depending on soil type, these emissions may have to be controlled |
| | Land farming | Contaminated soils are mixed with soil amendments (soil bulking agents and nutrients) and are tilled into the earth. The material is periodically tilled for aeration. Contaminants are degraded, transformed, and immobilized by microbiological processes and by oxidation. | - used mostly in oil contaminated soils<br>- successfully treated diesel fuel, fuel oils, oily sludge | - requires large areas,<br>- long treatment times,<br>- requires properly site management and control |
| **Chemical** | Soil washing | Separation of contaminants / contaminated soil particles from uncontaminated soil in a water-based system. Separation based on different physical properties of contaminated particles or chemical dissolution of contaminants. | - relatively fast<br>- suitable for a wide range of contaminants<br>- targets available contaminants | - preceded by soil particles size separation,<br>- may require additional processes for water treatment |

The choice of best available remediation technology for a given pollution is highly dependent on the pollutant composition, the depth of pollution, if the pollution is in the saturated or unsaturated zone, soil texture (sand, silt or clay), geology, the planned use of site, environmental goals for the site, and infrastructure. In remote areas as may be the case in some Arctic locations, the choice of relevant remediation technologies includes assessment of what will be practically possible. Installations that depend on well-founded infrastructure (electricity, roads) may not be relevant in some remote locations. In Arctic locations, the climate plays a key role in determining the best available technology.

***Biological treatment*** is a process whereby contaminants in soil, sediments, sludge or groundwater are transformed or degraded into innocuous substances such as carbon dioxide, water, fatty acids and biomass, through the action of microbial metabolism. Bioremediation is mostly used for stimulating degradation of organic pollutants; however, it can also be used to immobilize contaminants, and thus is relevant for both organic and inorganic pollutants. Bioremediation has previously been used in Arctic locations to stimulate degradation of oil pollution and has been shown to work in cold climates in Canada, Greenland, Norway and Russia. Phytoremediation is a bioremediation method that relies on degradation or immobilization of pollutants in the plants or root zone in the soil. Phytoremediation has been applied to a lesser degree in cold climates due to challenges with plant growth and mobilization during the melt season.

Biological processes are typically implemented at low cost. Contaminants can be degraded and often little to no residual treatment is required. However, the process is time-consuming, often spanning more than a year. This means it can be challenging to be used at sites with time frame or that are being developed. Without monitoring of the progress, it is not possible to determine whether contaminants have been completely degraded. Other challenges that have to be taken into consideration in the design is the risk of microbes being sensitive to toxins or highly concentrated contaminants in the soil. Cold climates can retard the degradation process and make bioremediation of persistent organic pollutants (such as PAH, PCB) challenging.

***Physico-chemical treatments*** use the physical and/or chemical and/or electrical properties of the contaminants or of the contaminated medium to destroy (i.e., chemically convert), separate, or contain the contamination. In the physical processes the phase transfer of pollutants is induced. In the chemical processes the chemical structure (and then the behaviour) of the pollutants is changed by means of chemical reactions to produce less toxic or better separable compounds from the solid matrix.

These treatments are typically cost effective and can be completed in short time periods (in comparison with biological treatment). Equipment for the remediation may be readily available (e.g. excavation), some of the more advanced physico-chemical treatments may however require design of equipment and installation. Compared to bioremediation, the physico-chemical methods are energy intensive, the energy consumption does however vary considerable among the methods.

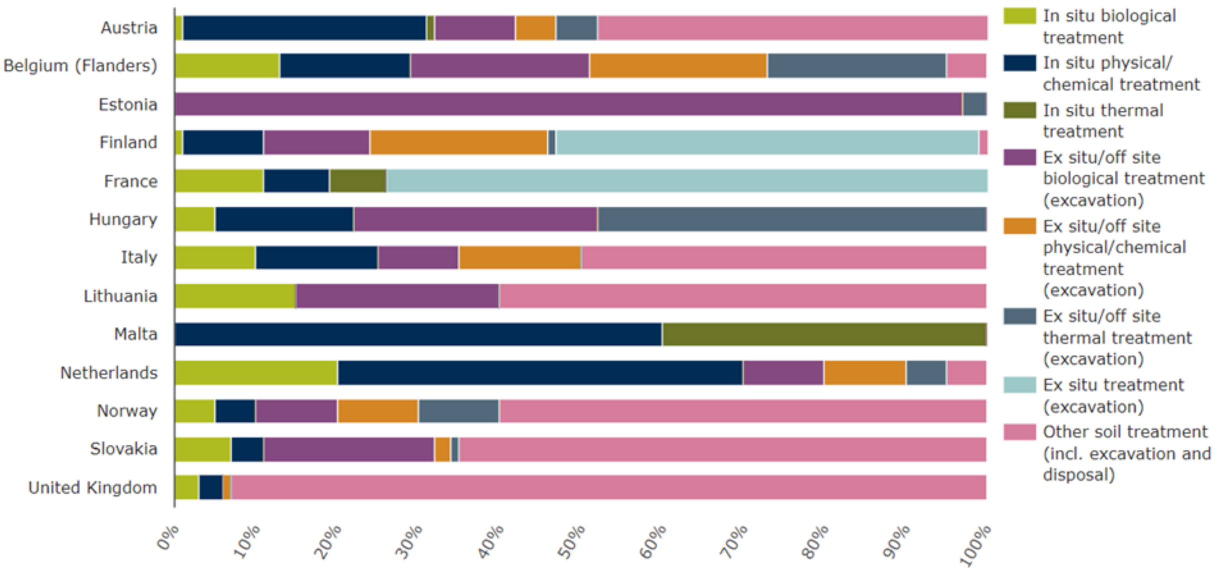
Certain in situ physico-chemical treatment technologies are sensitive to certain soil parameters. For example, the presence of clay or humic materials in soil causes variations in horizontal and vertical hydraulic parameters, which, in turn, cause variations in physico-chemical process performance.

In Arctic regions, excavation and transport to disposal site is the most common remediation technology, also for oil polluted sites. The oil polluted soil is easily excavated and transported to landfills approved for polluted soils, sometimes over several 1000 kms. The impact on climate gas emission is not part of assessing best available technology for remediation, but may be expected to impact the choice of remediation in the future.

***Thermal treatments*** are based on physical principles of separation and degradation of contamination. The driving force of the process is heat, used to increase the volatility, to burn, decompose, or degrade the contaminants. Generally, thermal methods offer quick clean-up times but are costly. Despite the high costs, the remediation technology can be cost-efficient for sites with large pollutions, mainly consisting of volatile and degradable organic contaminants such as oil pollution. Cost is driven by energy and equipment costs and is both capital and Operation & Maintenance (O&M) intensive.

Cleaning soil with thermal methods may take only a few months or several years. The time it takes depends on three major factors that vary from site to site: type and amounts of chemicals present; size and depth of the polluted area; type of soil and conditions present. The technology has been used in situ for clean-up of oil pollution at sites in Europe and North America. The main challenges of using the technology in Arctic regions is to ensure minimal disturbance to continuous permafrost layers and implementation of thermal electrodes in remote areas.

According to the European Environmental Agency (EEA), in 2006 "traditional" remediation techniques are most commonly used for the treatment of contaminated soil, in particular the technique of soil excavation and disposal is applied in about 30 % of the relevant sites. In situ and ex situ measures are applied with similar frequencies (Fig.1). Ex situ physical and/or chemical treatments are reported to be the most common (37 %) techniques used in the treatment of contaminated groundwater.




** marginal note 2*

**Fig.1. Most frequently applied remediation techniques for contaminated soil[3]**

Currently, about 40 % of all remediation sites are remediated by utilising some of the ***in situ*** methods, such as biodegradation accelerated by nutrients and oxygen, soil vapour extraction into active carbon or catalytic burner, electrical osmosis and chemical oxidation. After the in situ phase, excavation has sometimes been used to remove the remainder of the contamination down to predetermined target values. In situ methods alone (with no excavation needed) have been sufficient in approximately 10% of the completed projects. In 5% of all remediated sites, in situ methods have been used to treat associated groundwater contamination. In some cases, soil and water purification systems have been successfully connected by circulating purified water through the contaminated soil. There are many sites where excavation is required for removal of buried oil storage tanks. However, damage to surface areas can be minimised, if in situ remediation is utilised even as a combined method with excavation.

The cost of remediation has traditionally been the primary criterion for deciding upon remediation actions. The size of the contaminated area, the availability of remediation material, and the solutions for treatment of dredged material will strongly influence the costs. Often, the combination of infrastructure projects can give opportunities for synergies that may lower costs.

*Note: The combination of infrastructure projects has been the case in several remediation projects in Norway, where material from road construction has been used as capping material (e.g., in Kristiansandfjorden), or dredged material that has been stabilized and used for land extension (e.g.,*

[3] Data sources: Eionet NRC Soil data collection on contaminated sites provided by Joint Research Centre (JRC), Last modified 10 Mar 2017

*at quay 2 in Trondheim harbor) or utilized for harbor extensions (e.g., in Tromsø, Sandvika). Dredging is typically considered the most expensive method though capping can also be very expensive, in particular when using geotextile or active materials.*

The low use of in situ methods is often explained by uncertainty regarding their treatment effectiveness and risk reduction, long-term ecological effects, time consumption, and lack of knowledge and data on their suitability, especially in Nordic conditions.

The various techniques usually work well when applied to a specific type of soil pollution, though no readily available treatments were implemented that could clean all types of pollutants. Due to the complex nature of many polluted soils and the fact that pollution, in many situations, is due to the presence of a combination of different types of contaminants, it is frequently necessary to apply several remediation techniques (treatment train) to reduce the concentrations of pollutants to acceptable levels.

Specifically in Arctic regions, methods relying on groundwater or subsurface aquifers is not relevant in areas with shallow permafrost. In these areas, aquifers are often frozen in the ground and in situ methods will rely on other ways of increasing contact between chemicals, microfauna, soil particles and pollutants. In the warm season (> $0^oC$) controlled flushing of the pollution can increase the separation and degradation of pollutants. In remote locations with limited infrastructure, bioremediation (landfarming) of oil polluted sites has been increasingly used the past 10-20 years in the Arctic region.

## 2.2 APPLICABILITY OF REMEDIATION METHODS FOR OIL POLLUTION ELIMINATION

Crude oil is mainly made up of petroleum hydrocarbons (PHCs), with traces of metals. The structure and properties of the hydrocarbon compounds determine their toxicity and risk for the environment. Hydrocarbons consist of aliphatic and aromatic compounds. Aliphatic hydrocarbons are the most abundant fraction in crude oil and have linear or branched chain structures, that may be saturated (single C-H bonds) or unsaturated (includes double or triple C-H bonds). Aromatic hydrocarbons are made up of unsaturated hydrocarbons in a six-carbon ring structure and pollutants of concern in oil include benzene, toluene, ethylbenzene and xylenes (BTEX) and polyaromatic hydrocarbons (PAHs). Aromatic hydrocarbons that consist of a single aromatic ring include BTEX. PAHs contain two or more aromatic rings in their structure. 100s of PAHs have been identified, of these 16 were prioritized as high environmental concern by the USEPA and has also been adopted by European countries. The 16 PAHs were chosen based on their risk to human health and the environment, combined with their abundance and occurrence. There are other PAHs that are more toxic, but often their occurrence is at concentrations lower than the toxic threshold. PAHs occur naturally in oil and combustion changes the composition. It is hence possible to determine whether PAH pollution originates from the raw oil or due to combustion.

The structure and properties of the hydrocarbons determine their toxicity and fate in the environment. Toxicity for oil pollutions is mainly related to aromatic hydrocarbons, which can pose a risk for human health and the environment at low concentrations. Aliphatic hydrocarbons can pose a risk, but at higher concentrations. Some PAHs and BTEX are known to be carcinogenic and at high concentrations they can be toxic to soil and marine organisms at short term exposure. The mobility and thereby fate in the environment depends on the properties of the components making up oil pollution. Long-chained aliphatic hydrocarbons and high molecular mass PAHs (4 or more aromatic rings) are less water soluble and less volatile, with a lower risk of dispersion into the environment. BTEX, short-chained aliphatic hydrocarbons and some low molecular PAHs (2-3 aromatic rings) are volatile and have higher solubility in water making them more mobile and likely to disperse into the environment, via either air or water. The composition of the oil pollution along with soil texture, subsurface water conditions and topography affects the fate in the environment and thereby the choice of the best available technology for remediation.

Historic oil pollution may contain polychlorinated biphenyls (PCB). Due to their properties of chemical stability, low flammability and high dielectric constant, PCBs were previously used in insulating fuels such as transformer oil, as well as in lubricant and cutting oils. PCBs are persistent in the environment, pose toxic risk for humans and the environment at low concentrations and have been identified as a persistent organic pollutant to eliminate in the Stockholm convention. The production of PCBs was banned in the 1970s and 80s in the US and Europe. The production of PCB ceased in Russia in the late 1990s. Since PCBs are highly persistent and chemically stable, they are still found in the environment and remain a priority pollutant for environmental authorities. The presence of PCBs at oil polluted sites impacts the remediation strategy.

Remediation methods, used to mitigate oil polluted sites, and their effectiveness for treatment of soil from the main petroleum components are presented in Table 2.

**Table 2. Remediation methods, used to mitigate oil polluted sites***

** Legend*: ● Applies, ◉ With restrictions, ◎ Does not apply

| Methods | | PHCs | PAHs | Metals |
|---|---|---|---|---|
| ***In situ*** | | | | |
| **Biological** | Monitored natural Attenuation (MNA) | ● | ◉ | ◎ |
| | Biostimulation | ● | ● | |
| | Bioventing | ● | ◉ | ◎ |
| | Bioaugmentation | ● | ● | ◎ |
| | Air sparging (AS) | ◉ | ◉ | ◎ |
| | Phytoremediation (inorganic) | ◎ | ◎ | ● |
| | Phytoremediation (organic) | ● | ● | ◎ |
| **Chemical** | Chemical oxidation (ISCO) | ● | ● | |
| | Oxidation with Hydrogen Peroxide | ● | ◉ | ◎ |
| | Solidification/Stabilization (S/S) | ● | ● | |
| | Soil flushing | ● | ● | ● |
| **Physical** | Soil vapor extraction (SVE) | ◉ | ◉ | ◎ |
| | Electrokinetic | ◉ | ◉ | ● |
| | Electrochemical Remediation Technologies (ECRTs) | ● | ● | |
| | Solidification / Stabilisation (S/S) | ● | ● | ● |
| | Multi-phase extraction (MPE) | ● | ● | |
| | Two-phase extraction (TPE) | ● | ● | |
| | Hydraulic containment | ● | ● | ● |
| ***Ex situ*** | | | | |
| **Physical** | Excavation and off-site disposal | ● | ● | ● |
| | Complex sorting | ● | ● | ● |
| **Biological** | Composting | ● | ● | |
| | Aerobic bio-pile | ● | ◉ | ◎ |
| | Bioreactor | ● | ● | ◉ |
| | Windrow composting | ● | ● | |
| | Land farming | ◉ | ◉ | ◎ |
| **Chemical** | Soil washing | ● | ● | ● |
| **Thermal** | Incineration | ◉ | ● | ◎ |
| | Thermal desorption | ● | ● | ◉ |

As mentioned above, the choice of technology for remediation of soil contamination depends on various factors. As can be seen from Table 2, some techniques for cleaning-up of soil from oil and oil products can be applied independently, while some of the them require application of several remediation techniques to reduce or eliminate oil pollution.

## 2.3 FEATURES OF THE APPLICATION OF TECHNOLOGIES IN NORTHERN AND ARCTIC CONDITIONS

The remediation methods in Table 2 have been used to mitigate oil pollution around the world. There are however conditions in the Arctic regions that must be considered in the remediation strategy and lessons learned from oil spills in other more temperate areas may not be directly transferable. The effects of an oil spill will last longer than in temperate regions because oil components degrade more slowly under cold and dark conditions, and Arctic fauna and flora need longer time to recover. Implementation of remediation measures also presents challenges due to the extreme conditions of cold, ice/snow cover and winter darkness. In addition, areas in the Arctic with shallow continuous permafrost present challenges in the remediation strategies. When permafrost is present in the top 2-3 meters (e.g., Greenland or Svalbard), subsurface water aquifers do not exist and the oil will disperse vertically to the permafrost layer and horizontally along the permafrost barrier, and in some cases through cracks in the permafrost. The permafrost acts as a natural barrier, and the biggest risk of dispersion is during the melt season, in which high volumes of melt water can contribute to wash out of pollutants from soil, via water or small particles. These types of flushes are not encountered in other parts of the world. The effect of snow melt and permafrost, where relevant, need to be considered in remediation strategies, whether these are to prevent dispersion or clean-up remediation. In some areas of the Arctic there is also focus on limiting the damage of remediation on local fauna and flora, and not introducing alien species or chemicals that will impact biodiversity. In areas where relevant, ensuring no or limited impact of the remediation method on the permafrost and indigenous fauna and flora is also an important part of remedial assessments.

In the Arctic and other cold climate regions, remediation of oil polluted land has mainly been mitigated by excavation and transport to licensed landfill for disposal of polluted soil, and to a lesser degree bioremediation. Excavation and disposal have been employed in areas of development of with a tight timeline and is an easy and practical solution for many sites. In more remote locations, bioremediation efforts have been made. Petroleum products and oily wastes will change composition with time, which is caused by a combination of physical, chemical, and biological factors. Naturally occurring bacteria and fungi can use hydrocarbons as an energy source and thus help in the final clean-up of an oil spill, and this is exploited in bioremediation strategies. However, in the Arctic, the degradation will be slow due to the short season in which temperatures are high enough for bacteria and fungi to be active, potentially increasing the remediation time in cold regions compared to observations made in more temperate regions. When the pollution does not pose a risk for human health or the environment, natural attenuation has been a strategy, however it entails many years of monitoring to ensure that dispersion pathways do not change and that the pollution is being degraded. This has for instance been employed in the clean-up of oil polluted soil in Svea, Svalbard. Landfarming has been used to enhance degradation of oil spills in Arctic Canada and Greenland. It has been most efficient for lighter oil compounds such as BTEX, petrol, diesel, and less efficient for high molecular weight PAHs.

Observations made at sea show some of the same trends and for degradation of oil on land. In Beaufort Sea sediment, oil degradation was apparent only after eight months, even though the bacterial community could grow at temperatures below freezing. The slow rate of biodegradation, which has also been demonstrated in the Barents Sea, may have been due to a lack of nutrients. Another reason may have been that the physical and chemical characteristics of oil in cold water make it less available for the microbes. In contrast to temperate spills, natural cleaning after a spill in the Arctic may therefore take decades rather than years. This underscores the need for special care to protect sensitive areas against spills.

Remediation of oil polluted sites in northern regions poses unique *challenges*:

- Remote and northern sites are prone to high mobilization and on-site monitoring costs, associated with difficult and limited access to the site, limited local availability of equipment and personnel and short seasonal period of work.
- Climate restrictions, like cold temperatures and ice conditions, and short seasonal windows to conduct work may limit remediation options.

- Northern systems require climate-appropriate design, including consideration of deep ground freezing, permafrost, seasonal changes in soil conditions (spring melt and frost heave) and long periods without operator intervention, fuel supply, etc.
- Difficulties in procuring timely testing and analytical results may necessitate reliance on field screening, staged interventions and/or risk management.
- Cold temperatures can hamper biodegradation and microbial activity may only occur during the summer months, thus treatment time may take several years. Microbial activity may be possible in deep soil as temperatures (below permafrost) are relatively constant over the course of the year.
- Due to permafrost, only very shallow soils may be viable for excavation (active layer).
- Active soil and groundwater extraction and treatment systems may not be appropriate for remote northern sites without access to utilities or local operations and maintenance labour.
- Costs and logistics associated with transportation of contaminated sediment to existing disposal sites are often prohibitive, and may necessitate on-site treatment and disposal. On-site treatment often involves a high cost and high level of uncertainty,
- In less populated areas, risk management might require less intensive monitoring and control measures that those generally required in more densely populated areas.

Several techniques, including physical, chemical, and biological methods, are used to remediate oil contaminated sites in cold environments. Bioremediation is a promising option for remediation since it is effective and economic in pollution remediation with less undue environmental damages. There have been several cases of success in the polar regions, particularly in the Arctic and sub-Arctic regions. However, the challenges and constraints for bioremediation in cold environments remain large.

# 3. NORDIC COMPANIES AND INSTITUTIONS DEALING WITH OIL POLLUTION ISSUE

This chapter presents an overview of companies and institutions from Nordic countries: Sweden, Finland, Norway and Denmark dealing with oil pollution issues, which could be potentially engaged in relevant activities in the North-West Russia to contribute in improving the environmental status of the oil-related hot spots in the Russian Barents region.

## 3.1 SELECTION OF COMPANIES AND ISTITUTIONS

There are a great number of companies and institutions in the soil contamination and remediation field in the Nordic countries, covering everything from site investigations to remediation. To make the list relevant to the conditions in the area, certain criteria have been applied to qualify for the list. General criteria used to select companies and institutions for further scoping included:

- Relevance: Wide knowledge and experience in application of best practices to address soil contamination and oil pollution issues.
- Replicability: Absence of specific factors playing a substantial role in best practice feasibility such as lack of approbation of approaches, methods and techniques, absence of specialized and/or expensive equipment and facilities, lack of limited application of the approach and techniques.
- Applicability: The capability of the approaches and techniques to be understood, learned, easy operated and attractive to the user.

Danish companies and institutions were included in the list as they have wide and modern experience in management and remediation techniques in oil pollution remediation, including experience from Greenland. State authorities have been excluded in spite of their experience, as they mainly deal with environmental management, rather than with site management and remediation. Higher education institutions were however included in the list due to their on-going research in contaminated sites, extensive knowledge and case studies in the related field.

*Note: Denmark performed an extensive clean-up of petrol stations, which were carried out and financed by the Oil Association. Although they did charge 5 øre extra per liter petrol/diesel to finance the clean-up. Thus Denmark has more experience in oil pollution remediation than, for example, Norway does.*

When compiling the list of companies, it became clear that companies could be listed in three categories according to their *areas of responsibility*. Therefore, the companies are listed in the following sequence: consulting companies, laboratories, remediation companies. This division was made for easier analysis of the list and search for companies of interest.

The list was *further elaborated* to identify competence and experience of the companies in each specific service area related to soil contamination and remediation. The *service areas* were split up in:

- Geographical area of operations
- Oil remediation
- ESA
- Soil remediation
- Sampling
- Testing
- Equipment

*Geographical area of operations:* This criterion was selected aiming to identify companies and institutions, which have working experience in the Barents and/or Arctic regions, and international experience as well.

*Oil remediation:* More often, Nordic companies, dealing with soil contamination, provide services for major projects on demolition (to be used for new purposes) and construction (new developments), than for typical abandoned facilities or oil-polluted sites. Such projects include wide range of activities on soil contamination, which are not necessarily associated with oil pollution each time. This criterion is used only where the information is readily available.

*Environmental Site Assessment (ESA):* This criterion includes such services as screening, investigation, survey, delineation, environmental site assessment, risk assessment, remediation measures design and remediation plan, monitoring, but not the physical remediation works itself.

*Soil remediation:* As a rule, companies provide site management during remediation works, according to remediation design and remediation plan. Sub-contractors, which have necessary equipment and labour, perform remediation works.

*Sampling:* Sampling is important issue for the Russian decision-makers and practitioners. Therefore, it was important to study the existing approaches and practices in the Nordic countries.

*Analysis (chemical):* Even if laboratories do not perform remediation activities, they are an integral part of the process of soil contamination management and remediation. Some of laboratories, located in the Russian part of the Barents region, have limited capacity and may not be able to analyze required oil components and other pollutants at all times. Study of Nordic experience could be beneficial for the Russian side.

*Equipment:* Usually remediation companies, which have necessary equipment and expertise, perform site remediation by request of consultancy companies. This criterion is aimed to identify such companies and consider its possible contribution to the sector's development in future.

In addition, the list is *divided by country*. However, multinational companies with offices in all or most of the Nordic countries are listed first.

The list is believed to include all relevant companies and institutions in the countries (see Annex 1). Mapping of Nordic companies, operating in soil contamination and oil pollution remediation, was carried out by use of Internet sources based on user searches, analysis of Nordic networks membership, Nordic participation in relevant events and case studies, and consultations with Barents stakeholders (incl. TF CA and NEFCO). Despite this, it can be assumed that some of the companies are still missing.

## 3.2 EVALUATION OF NORDIC COMPANIES AND COMPETENCE

### *European and Nordic Networks*

To harmonize available data and share information among a great number of Nordic and European institutions and companies dealing with management and remediation of contaminated soil, European and Nordic countries have established specific networks to collect, share and discuss information to address soil contamination and remediation issues, among which are:

**Eionet** - The European Environment Information and Observation Network, https://www.eionet.europa.eu
Eionet is a partnership network of the EEA and its 39 member and cooperating countries. The Eionet Portal is the primary entry point to all the web-based tools and services available for networking, information sharing and data collection. The Eionet portal hosts both publicly accessible information and information only accessible by logged in users.

**ESDAC** - European Soil Data Center, https://esdac.jrc.ec.europa.eu
ESDAC is the thematic joint research center for soil related data in Europe. Its ambition is to be the single reference point for and to host all relevant soil data and information at European level. It contains a number of resources that are organised and presented in various ways: datasets, services/applications, maps, documents, events, projects and external links.

**NICOLE** – Network for Industrially Co-ordinated Sustainable Land Management in Europe, https://nicole.org
NICOLE is a leading forum on industrially co-ordinated sustainable land management in Europe, promoting co-operation between industry, academia and service providers on the development and application of sustainable technologies. The overall objective is to pro-actively enable European industry to identify, assess and manage industrially contaminated land efficiently, cost-effectively, and within a framework of sustainability.

**COMMON FORUM** on Contaminated Land, www.commonforum.eu
COMMON FORUM is a network of contaminated land policy makers, regulators and technical advisors from environment authorities in European Union member states and European Free Trade Association countries. The network is a platform for the exchange of knowledge and experience, for initiating and following-up on international projects among member states and a discussion panel on policy, research, technical and managerial concepts of contaminated land within the European countries. COMMON FORUM holds regular meetings to discuss current legal, technical and organizational issues in the field of contaminated land management and land recycling.

**NORDROCS** - Nordic Conference Panel on Remediation of Contaminated Sites, http://nordrocs.org
The objective of NORDROCS is to address issues on assessment and remediation of soil, groundwater and sediments in the context of Nordic conditions. NORDROCS arranges thematic conferences each second year. The objective of the conferences is to address issues on assessment and risk management of contaminated land and sediments in the context of Nordic conditions. The meeting intends to provide a forum for the exchange of information gathered through research and project experience. Target groups include scientists, regulators, consultants, contractors and other professionals working with contaminated sites and sediments in Nordic countries, countries in Northern Europe and around the Baltic Sea.

**Renare Mark, Sweden** - Clean Soil Network, http://www.renaremark.se
The goal is to increase communication and exchange of knowledge between different groups of expertise regarding contaminated soil, sediments and groundwater.

**MUTKU, Finland** – Soil Research and Remediation Association, https://www.mutku.fi
The purpose of the association is to develop and promote activities and practices related to contaminated land, to promote cooperation and professionalism among all those working in the field. The main forms of activity are organising training events and informing members.

**Miljøringen, Norway** - Network for Contaminated Soil and Sediments, https://miljoringen.no
Miljøringen is a link between the members and public authorities, R&D environments and international networks, providing exchange of information and create better foundation for selection of environmentally sound and cost-effective technologies for clean-up contaminated soil and sediments.

**ATV Foundation on Soil and Groundwater, Denmark**, http://www.atv-jord-grundvand.dk
The Danish ATV Foundation on Soil and Groundwater was founded with the objective to promote, enhance and exchange knowledge and research within the field of remediation of soil and groundwater contamination. The foundation works to initiate and stimulate education, research and development as well as promoting the professional debate within this sector.

The four Nordic networks on contaminated sites are communicating and cooperating on permeant basis. As members of the Organizing Committee of the NORDROCS conferences, they have together successfully arranged conferences since 2006. The next conference is planned for September 6-7, 2022, Oslo. Each network has several events during the year – conference/workshops with specific topics within contaminated sites.

## *Nordic Companies and Institutions*

Land redevelopment, construction works, and cessation of industrial operations are the main reasons for remediation. The companies and institutions listed in Annex 1 have wide knowledge and experience in soil and oil contamination and remediation in their own countries, in some cases worldwide. They can be divided in separate groups according to their areas of responsibility: consulting companies, laboratories, remediation companies, and academia.

***Consulting companies*** present the largest group. As a rule, consulting companies provide management, supervision works and monitoring of the contaminated site.

Consultancy and management works include:

- screening
- investigation
- survey
- delineation
- environmental impact assessment
- risk assessment
- remediation plan
- monitoring

To perform soil remediation measures, consulting companies enter into contracts with sub-contractors, which have relevant technical/machinery skills, equipment and labour, for execution of such works. During remediation works, consulting companies provide site supervision according to remediation measures design and remediation action plan.

Some of the companies conduct their own research works to develop and approbate remediation methods. Some times, research work is based on testing of new technologies that appear on the market, and other times it is the result of cooperation between company and university.

Nordic soil contamination sector is also presented by multinational consulting companies with offices in Sweden, Finland, Norway and Denmark. These companies are multidisciplinary companies, where environment protection and soil contamination are one of the sectors of their economic operations. Some of companies have offices worldwide (Asia, Africa, Europe, America, Australia). Thus, they have international experience, which could be useful for future activities in the Barents and Arctic regions.

In some cases small consulting companies provide only management, and not remediaton, services in full or in part, depends on the task. However, these companies were included in the list to get a full overview of the companies working in this sector. They have deep knowledge and experience in their own countries and may be useful for the Barents and Arctic activities addressing soil contamination and oil pollution issues due to their specialised products/services.

***Laboratories*** are an integral part of the soil contamination and remediation activities. Nordic laboratories have extensive experience and extensive instrumentation for sample preparation and analysis. They offer customers a very wide range of analyses, as a rule on all types of water from purest dialysis water to dirty wastewater and on solid samples such as soil, sediment, sludge, biota, waste and building materials. There is a tendency to outsource these services to Eastern European countries.

Generally, consulting companies provide sampling themselves or hire sub-contractor for this purpose. However, some large laboratories can offer sampling services as well.

The practical issues related to communication, sampling, delivery of samples deserve special attention. Laboratories have a well-prepared product catalog of analyses and product sheets that are very helpful when business decisions are to be made. They offer on-line system for ordering sampling packaging, as it is very important that all samples be taken in the right type of sample vessel. Laboratories have well-established transportation system, where you can book a transport for delivery of samples and provide customers with packaging leaflets, which can be downloaded from their websites.

In addition to analyzes, some large laboratories also offer courses and seminars related to various industries and contaminations in the form of open courses or  tailored course for particular business and geographical location.

***Remediation companies*** present a small group and are represented by companies dealing directly with soil remediation or having own waste disposal and treatment facilities. They carry out complex demolition and remediation projects related to soil and water contamination, including oil pollution, offering sampling, soil and water treatment, and soil remediation. These companies have skilled and experienced staff, own equipment and facilities. Some of the companies conduct own activities on development and approbation of different remediation methods, often in collaboration with universities or consultancy companies.

Remediation companies have wide knowledge and experience of applying different in situ and ex situ methods for remediation of contaminated soil. In order to get a better basis for planning and application of optimal methods, they may also carry out pilot experiments. It can e.g. be sample pumping, filtration, pit excavation, sieving and dewatering of soil masses or sediments. As a rule, the method that is most cost-effective for particular remediation measure is recommended.

***Academia*** aim at developing new knowledge and technologies, and soil contamination and remediation is an integrated part of these activities. The services may range from research, mapping, testing, monitoring, demonstration, research facilities and laboratory resources, publications and research data to training and dissemination.

Universities and research institutes have accumulated wide knowledge and experience in soil contamination and remediation issues through conducting their own designs or by participating in commissioned assignments, which also contribute to sector development. Often they have more specific knowledge of contaminants, pathways and remediation methods, than consultancy companies do. Thus, the academia might be considered as an important resource when implementing relevant international activities in the future.

### *Companies, operating in the Arctic and Barents Regions*

Generally, the companies or head offices of the companies are located in the larger cities (Sweden, Finland, Norway - southern and central parts, Denmark – eastern part), where more economic activity is concentrated. Some of the companies have their representative offices in the northern regions. Skilled staff from the main offices could be engaged to assist local staff in certain works if situation so requires.  In the absence of offices in the Northern regions, staff from the southern and central offices can be directly involved in performing of commissioned tasks.

Information on companies and universities websites and conducted consultations with Barents and Nordic institutions mentioned above not always give clear understanding about companies’ operating experience in the Barents and Arctic regions. Certainly large international consulting companies have working experience in soil remediation in cold environment. It can be anticipated that majority of the Swedish, Finnish and Norwegian companies have also working experience from the Northern regions. All of the universities have worked in the cold environment under different collaboration projects. Swedish, Finish and Norwegian universities have definitely working experience in the Northern regions and Danish – in Greenland. Few companies were identified having working experience in Russia:  Engwater Oy (Finland), Lamor Corporation (Finland), Ramboll Finland in the field of geotechnics, Savaterra (Finland), SGS Finland (laboratory), SINTEF Narvik (Norway), Akvaplan-niva (Norway), Krüger-Veolia (Denmark), and EUROFINS (laboratory).

Listed companies and institutions have wide knowledge in soil contamination and oil pollution issues and experience of applying different methods for remediation of contaminated sites. Thus, it has been anticipated that they could be interested in working in international cooperation and share their experience with Russian side. However, no contacts have been made to inquire about such interest, as needs and demands are not specified yet. Considering the wide range of services, the companies could be contacted depending on the needs of Russian stakeholders and the goals and tasks of a particular activity for the Russian part of the Barents region.

# 4. MAPPING OF SIMILAR ISSUES AND CONDITIONS IN RUSSIA

The Consultant carried out mapping (desktop inventory) of appropriate issues related to soil contamination, including oil pollution, and remediation, in Russia. This chapter briefly describes soil and oil contamination and remediation approaches and conditions (technologies, methodologies, rules, financing) in Russia.

Contaminated sites management and remediation are very important issues for the Russian Federation. Therefore, oil-related pollution issues have a high priority in Russia and in North-West Russia in particular. The Russian Ministry of Natural Resources and Environment (MNRE) and the regions are investing heavily in different activities in order to improve the environmental situation. Each of the regions has similar kind of objects that are included in the list of environmental hot spots: Hot Spots A-6, A-7, A-8, A9-2, M-10, K9, N1, N-3, Ko8.

### *General position*

The Land Code of the Russian Federation (RF) stipulates that persons using land plots are obliged to carry out soil remediation measures. Contaminated sites of all categories are subject to remediation, as well as adjacent land plots that have completely or partially lost productivity as a result of the negative impact of contaminated site. The list of major existing federal legal and regulatory framework, governing the elimination and remediation of the contaminated soil on the territory of the RF, is presented in Annex 2.

In accordance with the Regulations of Land Reclamation and Conservation (approved by RF Government Resolution of 10.07. 2018 No. 800), assessment and remediation of soil contamination, occurred due to economic activities of legal or private entity, are carried out at the expense of legal or private entity own funds.

The legal framework in the field of elimination of accumulated environmental damage is regulated by the Federal Law "On Environmental Protection" (10.01.2002 No. 7- FZ, under Articles 80.1 and 80.2). Federal, regional and/or municipal authorities carry out identification, assessment and remediation of contaminated soil on the sites of the accumulated environmental damage.

The works on elimination of soil contamination include related surveys, including engineering surveys, the development of a remediation project, its coordination and approval, remediation work, control and acceptance of the work performed.

The main *types of engineering surveys* are:
- engineering and geodetic
- engineering and geological
- engineering and hydrometeorological
- environmental engineering
- engineering and geotechnical

The selection of *remediation categories* is determined in accordance with the terms of National Standard (GOST) 17.5.1.02-85 classification of disturbed lands to be remediated and GOST R 57447-2017 on best available technologies:
- agriculture
- forestry
- fishery
- environmental protection
- recreation
- water management
- construction

The development of *design and estimate documentation* on the remediation of oil polluted soil is carried out based on existing environmental, sanitary and hygienic, construction, water management, forestry and other norms and national standards, taking into account regional climatic conditions and the location of the oil contaminated site. Design and estimate documentation on the remediation of oil polluted soil is a subject to approval by the authorized state and local authorities in accordance with the current legislation.

Remediation of contaminated soil should be carried out in two successive stages in accordance with the terms of GOST 17.5.1.01-83 on land reclamation and with consideration to the existing best available technologies.

*Technical stage* includes:

- Limiting the spread of pollution outside boundaries of the occurred oil spill by collecting surface oil and using oil collection facilities, machines and mechanisms.
- Complex of works on elimination of sources and consequences of negative impact and maximum possible reduction of the level of residual soil pollution by oil and oil products.
- Planning, formation of slopes, removal, transportation and application of a fertile soil layer, the construction of hydraulic and reclamation installations, as well as other measures necessary for the implementation of subsequent remediation work.

*Biological stage:*

- Aims at maximum possible additional cleaning-up of soil from the remaining pollution after technical stage and creation of favorable conditions for the restoration or self-restoration of biocenoses.
- Is carried out after the full completion of the technical stage. It should be carried out with consideration to requirements for soil remediation for each specific category.
- Includes a set of agrotechnical and phytomeliorative measures to restore soil fertility (GOST 17.5.1.01-83). This stage of remediation corresponds fully to agricultural and forestry categories only. For other land categories, the biological stage is not carried out over the entire remediaton area.

### *Financing*

Assessment and remediation of soil contamination, occurred due to economic activities of legal or private entity, are carried out at the expense of these legal or private entity own funds. In case of elimination of accumulated environmental damage, where the owner of the contamination could not be identified, federal, regional and/or municipal authorities carry out identification, assessment and remediation of contaminated site.

State support to eliminate of accumulated environmental damage is provided under the Federal Project “Clean Country” of the National Project “Ecology”. The Federal Project “Clean Country” (further – Clean County Project) aims at reducing the negative environmental impact by eliminating accumulated environmental damage, including remediation of oil polluted sites, and demolishing of (former) illegal dumps within the boundaries of the cities. Each subject of the Russian Federation has regional programmes on environment protection and “Sites of the Federal Importance”, which have a potential to be included in the Clean County Project.

*Project priority - accumulated environmental damage*: The selection of projects for inclusion in the Clean Country Project is carried out based on information provided by the subjects of the Russian Federation on the objects of accumulated environmental damage, as well as taking into account the rules for the provision and distribution of subsidies from the federal budget.

*Project selection criteria:*

- objects are not operated
- the objects are owned by the subjects of the Russian Federation or municipalities
- availability of endorsed design and estimate documentation
- availability of the necessary examinations provided by the Russian legislation

- environmental and social benefit from project implementation (the number of population exposed to negative impact, the area of the contaminated area)
- co-financing from the subject of the Russian Federation

*Implementation of priority project:* Elimination of the accumulated environmental damage, that represent the major environmental risks, will ensure:

- drawing into economic circulation of remediated land
- improving the quality of land
- increasing the investment attractiveness of the land that previously experienced a negative impact from the accumulated environmental damage

For instance, in 2020 work was carried out to eliminate 22 site of accumulated environment damage and 23 illegal landfills in Russian subjects. 51 measures are planned for 2021, 20 of which aiming at elimination of accumulated environment damage and 31 – at elimination of illegal landfills. Project works, started earlier at some sites, continues in 2021.

### *Project Examples*

In the framework of the Clean Country Project, the following *projects* were implemented, are under implementation or will be implemented *in the Russian part of the Barents region*:

*Implemented*

- The Arkhangelsk region
  - Elimination of oil pollution in the water protection zone of the Kuznetsov stream, the Mezen district

*2021*

- The Murmansk region:
  - Remediation of manure storehouse of former poultry farm “Snezhnaya”, Molochny settlement
  - Remediation of the solid waste landfill in Murmansk, “Structure 1”

*2022-2024*

- The Arkhangelsk region, remediation and elimination of illegal landfills:
  - The town of Mezen
  - Arkhangelsk, the Maimaksa territorial area, the Brevennik island, Emetskaya street
  - Arkhangelsk, the Maimaksa territorial area, the Brevennik island, Yung Marine street
  - Arhhangelsk, the Solombala district, the Khabarka island
  - Arkhangelsk, the Severnyi territorial area
- The Republic of Karelia, remediation and elimination of illegal landfills:
  - Elimination of the site of the accumulated environmental damage in the town of Belomorsk
  - Remediation of the waste landfill in the town of Pudozh

In recent years, not only ex situ, but also in situ methods have been actively tested and applied for remediation of contaminated soil and oil pollution in Russia. Along with physical methods, biological methods of contaminated soil remediation are increasingly being used. Particular attention is paid to the implementation of the best available technologies (described below) to clean-up contaminated soil. Modern technologies are most widely implemented in large-scale state projects or at large industrial companies in oil, mining, processing and transport sectors, which, as a rule, have their own research institutes and skilled staff of environmentalists, technical and financial resources.

Projects, implemented under the Clean Country Project, have a positive experience addressing soil contamination issues and typify application of modern technologies, including bioremediation methods:

- Remediation of the accumulated environmental damage - industrial site of the Usolkhimprom company, city of Usolje-Sibirskoye, Irkutsk region, area of 16 $km^2$
- Disposal and treatment of all type of waste of the Baikal Pulp and Paper Mill, Irkutsk region
- Elimination of toxic waste landfill “Krasnyi Bor”, Leningrad region, approx. 2 mln. tons
- Remediation of solid waste landfill «Igumnovo», city of Dzerzhinsk, Nizhnyi Novgorod region, waste volume – 5.5 mln. $m^3$, excavated soil – 0.42 $km^2$

- Elimination of industrial chemical waste landfill “Chyornaya Dyra” of former Orgsteklo enterprise, city of Dzerzhinsk, Nizhnyi Novgorod region, waste volum – 2-7 mln. tons

*Note: Chemical waste landfill “Chyornaya Dyra” - the lake with an area of 15 000 m$^2$ is included in the Guinness Book of Records as "the most polluted small water body in the world." The exact composition of chemicals is unknown, but there are definitely heavy metals arsenic, lead and cadmium. Birds and insects, that fly there, get stuck in the lake and stay there forever.*

- Remediation of sludge storage «Beloye Morye» on the terriotory of Kaprolaktam enterprise, city of Dzerzhinsk, Nizhnyi Novgorod region, waste volume -3.95 mln. m$^3$, excavated soil – 0.66 km$^2$
- Project examples on environmental surveys and remediation methods in mining industry, presented at Contaminated Sites Management-Related Training in 2020-2021, SHE Support Activity No 2.

Despite the obtained results and certain successes in the development and application of advanced remediation technologies, it is too early to anticipate the widespread introduction of the best available technologies of contaminated soil remediation; this applies to small municipal projects in the Russian Federation, and in the Russian part of the Barents region as well. This situation is due to a number of reasons, such as the lack of qualified specialists at the local level, the lack of proven technologies for the appropriate conditions in these regions, the lack of funds for the implementation of projects that would include not only excavation of soil and its treatment, but also testing of possible remediation methods for each specific project, and etc. However, taking into account the experience gained in the framework of the implementation of large-scale projects in the Russia, it can be expected that the implementation of projects using the best practices and cost-effective technologies will be possible in the Russian regions in the near future.

## *Remediation of oil polluted soil (best available techniques)*

Features of remediation of oil polluted land are detailed in GOST R 57446-2017 “Best available techniques. Remediation of land contaminated with oil and oil products. Basic principles.” Selection of best available techniques (BAT) is based on RF Government Resolution No. 1458[4], Guidelines for determining technology as the best available[5], and provisions of GOST 33570-2015. At the same time, technologies that correspond to one of two approaches can be classified as BAT:

- traditional technologies of technical and biological remediation,
- remediation technologies for oil polluted soil aims at restoration of biological diversity that complements traditional ways.

The remediation techniques of oil contaminated lands listed in GOST R 57446-2017, p. 8.2-8.3 are based on modern science and technology achievements and the best combination of criteria for achieving environmental protection goals and economic feasibility, as well as on condition to technical availability of their application and implementation at a minimum of two Russian enterprises. The methods to be used at technical and biological stages are presented below.

### *Technical stage*

- Limitation the spread of soil pollution outside boundaries of the occurred oil spill includes the following methods
  - Construction of containment dike using dense soils (clay, loam)
  - Use of oil containment systems (barriers, dams, hydraulic locks, containment channels, booms)
  - Collecting oil from the surface of water and soil
    - waterflooding with subsequent activation of oil desorption and its collection

[4] Resolution of the Government of the Russian Federation of 23.12.2014 No. 1458 “On the procedure for determining technology as the best available technique, as well as development, updating and publishing BAT Reference documents (BREFs).”
[5] Approved by Order of the Ministry of Industry and Trade of Russia of 31.03.2015 No. 665

  - sump application
  - installation of drainage channels in the winter-spring period
  - dredging to remove oil from the surface of swampy ground with scrapers and dredges
  - installation of oil skimmers or drum oil skimmers
  - vacuum pumping of oil from the water surface

- Physical and chemical techniques
  - soil flushing with surface active compound (surfactants)
  - soil drainage (can be combined with the use of oil degrading bacteria)
  - solvent extraction (usually carried out in drum washing with volatile solvents)
  - steam extraction (in a vacuum chamber)
  - sorption (surface cleaning up using sorbents)
  - thermal desorption at 100-550 °C
  - excavation and separation

Physical and chemical methods are used for oil pollution remediation both independently and in combination with other methods.

*Biological stage*
- bioremediation with oil degrading biologics
- bioremediation with organic manuring
- bioremediation with fertilizer dressing
- phytoremediation - sowing of grass and tree planting

Various in situ methods are recommended and applied for *oil sludge and wastewater treatment*:

*Oil sludge:*
- separation (for liquid oil sludge)
- washing (using hot solutions with surface active compound (surfactants))
- passive phase separation (using surfactants and subsequent biological post-treatment of water and solid oil sludge)
- composting (using waste – waste sludge from treatment facilities, plant waste, special biologics)
- biostimulation (using oil degrading biologics)

*Wastewater:*
- filtration
- separation
- sorption
- biostimulation
- oxonolysis

The selection of methods for bioremediation of oil polluted soil is determined with due regard to peculiarities of natural and climatic conditions, biodiversity, achieved level of soil treatment at the previous technical stage, economic and environmental feasibility, intended purpose of land use.

Various remediation agents are used to activate the biological processes of soil cleaning-up from oil and oil products, such as oil degrading biologies, sorbents, organic and mineral fertilizers, agrochemicals based on humic compounds, grass mixture.

Biologics are developed based on oil-degrading bacteria and are manufactured in three main forms: liquid, pasty and dry.

Biologics must meet the following requirements:

- have an increased specificity for the biodegradation of the pollutant (oil product) prevailing at the site to be remediated
- be produced based on nonpathogenic strains isolated from natural ecosystems, preferably local
- have a high ability to utilize hydrocarbons in a short time
- be environmentally friendly to the ecosystem
- be manufactured in accordance with the Technical Specifications and supplied with detailed user's manual
- have permit to use in accordance with the Russian legislation
- be fire- and explosion-proof, and non-toxic for the personnel during delivery and use
- be applicable of transport by any available transport means at any distance in strong packing, that does not deteriorate and does not violate their properties

In the main, application of fertilizer dressing and application of biologics are combined in a single dose and are carried out at the same time under soil bioremediation stage. In addition, these two techniques are supplemented by rotary cultivation method. This combined method is widespread and has shown its effectiveness in the conditions of the Northern regions in rugged wetlands, which are typical for the Russian Barents region as well.

Bioremediation with organic manuring is necessary if the soil is slightly humic or represented by mineral soil (sand, clay), and the level of oil pollution is very high. In the Far North, where there are practically no livestock farms with a sufficient yield of organic fertilizers and conditions for compost preparation, it is possible to use peat as a structurer and underground lifter.

The application of peat is widespread under the remediation methods of oil polluted soil. Peat acts as a sorbent and a component, which improves the physical properties of the soil.

An alternative to peat can be organic sorbents of plant origin, obtained under industrial conditions and used for post-treatment of soil. The sorption method of eliminating residual pollution is applicable, in the absence of deep pollution, for soil post-treatment in places that are not accessible for soil loosening/rotary cultivation by a mechanical means.

The chemical remediation methods of excavated contaminated soil, that exist today, are practically not common, since they are extremely difficult to use due to the high cost of the chemical reagents, the impossibility of treatment of large volumes of contaminated soil, or treatment of soil containing high concentrations of pollutants.

It is generally accepted that physical and chemical methods of soil remediation are more reliable and efficient than the corresponding bioremediation methods. The efficiency of physical and chemical methods, as a rule, depends less on the specific characteristics of the contaminated soil (water) and practically does not depend on the climatic conditions at the contamination site. For bioremediation methods the influence of these uncontrolled factors can be decisive.

For a long time, the mechanical method was the main method of oil pollution remediation in Russia. Nowadays, bioremediation and in particular application of bacteria to accelerate the oil decomposition in soils has become more widespread.

In Russia, when carrying out remediation work on large oil polluted territories, for some reason (both environmental and economic), preference is given to two methods of biological soil purification: activation of natural oil decomposition by agricultural methods and bioremediation with oil degrading biologics. A combination of both methods is widely used[6].

[6] Environmental work at oil and gas enterprises. Part I. Remediation of oil polluted land in the Usinsk region of the Komi Republic. - Syktyvkar, 2006.- 208 p. - (Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences).

In recent years, technical solutions on remediation of oil polluted soil and water bodies after accidental oil spills are increasingly based on problem solving integrated approach - scientifically defined optimal combination of technical and biological methods of remediation, selected in consideration to the specifics of the remediated sites.

The specificity of work to eliminate oil pollution significantly differs from the established procedure and rules for remediation of contaminated soil, including in terms of assessing work quality, determining the duration and sufficiency of remediation work, etc. In this regard, some subjects of the Russian Federation have developed and put into effect their regional regulatory and legal framework. For example, Komi Republic has formed the requisite regulatory framework: requirements for technologies on remediation of oil polluted lands in the Far North, rules and regulations for the acceptance of land and water bodies after remediation work, including substantiation of residual concentration of oil and oil products in soil.

# 5. IDENTIFIED NORDIC COMPETENCE AND TECHNOLOGIES RELEVANT FOR IMPLEMENTATION IN NW RUSSIA

The problem of clean-up of accumulated environmental damage, and oil pollution in particular, appeared in Russia quite a long time ago and has become very acute. There is no region in Russia the environment of which has not been damaged. The areas most susceptible to environmental damage today are the territories near settlements and industrial lands. The environmental threat grows each year. Therefore, the problem of clean-up of the contaminated land needs to be addressed as soon as possible.

Analysis shows, that Nordic companies obtained wide knowledge and experience in addressing soil contamination and remediation issues, which have a great value for the Russian sector's development. Transfer of knowledge in environmental management and application of best environmental practices (BEP) for elimination of soil contamination will certainly contribute to cleaning up of oil pollution in the Russian Barents region.

Contaminated site management and remediation is a very important issue for the Russian Federation and for the Russian Barents region in particular. Technically, many more or less well-functioning solutions are available in Russia. However, appropriate compilations and evaluations of different environmental management approaches and remediation methods and techniques are lacking. Application of Nordic best approaches and practices on investigation, assessment, management, and remediation of contaminated site will help planning and decision making in all the steps of the remediation of polluted site.

The main steps of the contaminated site management and remediation process are:

- Identification of Contaminated Site
- Environmental Site Assessment (ESA)
- Environmental Impact Assessment (EIA)
- Sampling Strategy and Analyses
- Environmental Risk Assessment (ERA)
- Remediation Design and Remediation Plan
- Remediation of Contaminated Site
- Monitoring during and after

Brief description of the steps (except two last) and to what extend they are relevant for application in North-West Russia are presented below.

### *Identification of Contaminated Site*

Identification of contaminated site is the first step, where studies on the site to characterize the pollution in its breadth and scope to be carried out in order to define the actions to undertake clean-up activities later. The investigations conducted on the site defines environmental compartments and study samples to be taken in order to ultimately develop the conceptual site model. Preliminary site inspection is carried out to meet three specific objectives: a) describe the site, b) examine the type of contamination and c) define the mechanisms of contamination mobility and the points of exposure. The results of this step will contain the information required to draw conclusions and determine whether or not a more in-depth analysis is needed.

This measure is more related to responsibility area of regional and municipal environmental authorities and decision-makers. Information, obtained during this step, is used by regional environmental authorities to develop ToR and tender documentation for carrying out of remediation actions of the identified contaminated site. The major difficulty for the regional authorities, which do not have professional ecologists, at this stage, are activities to determine the boundaries of pollution and define sampling plan. A good selection of points of exposure is extremely important, as environmental sampling should be comprehensive.

Despite the apparent insignificant volume of work, the most relevant for exchange of experience are issues related to site delineation and sampling planning.

### *Environmental Site Assessment*

Environmental Site Assessment is carried out when a pollution has happened. ESA includes mapping of historical events and sources, investigations, sampling, environmental risk assessment, and remediation design and plan, and monitoring plan, if necessary.

ESA is designed to characterize the nature and extent of contamination identified through preliminary investigations and, more importantly, provides the information that enables comprehensive evaluation of remediation options and quantification of liability. Planning and executing the ESA requires anticipation of how the contamination may be remediated or managed. Base on a compilation and evaluation of all field observations, field measurements, and laboratory analytical data, a customized remediation option(s) and a detailed engineering design are developed.

Russia has comprehensive legal and regulatory framework, governing activities on environmental site assessment and describing requirements and procedures for different types of investigations and assessment of contamination including ToR, work program, scope of investigation. Engineering and geological investigations in areas of permafrost are carried out having consideration for regulations of works in these conditions. Technically, many well-functioning regulations and methodologies related to ESA are established in Russia. However, appropriate knowledge and application of best practices in certain activities under ESA, like sample planning, risk assessment, drafting remediation design and plan, are lacking. Several issues were briefly touched upon during the recent training - Contaminated Sites Management-Related Training under SHE Support Activity 2 in 2020-2021. Further transfer of Nordic knowledge and competence in the mentioned specific activities will, certainly, promote awareness raising of local experts and practitioners.

### *Environmental Impact Assessment*

Environmental Impact Assessments is similar to ESA and differ in that it is carried out before to a planned industrial project or development. EIA is a process of evaluating the likely environmental impacts of the site, and are used to identify the environmental, social and economic impacts of a project prior to decision-making.

By using EIA both environmental and economic benefits can be achieved, such as reduced costs and time of project implementation and design, avoided treatment/clean-up costs, etc. The fundamental components of an EIA would likely involve the following stages:
- Scoping to identify which potential impacts are relevant to assess, to identify alternative solutions that avoid, mitigate or compensate adverse impacts on biodiversity;
- Assessment and evaluation of impacts and development of alternatives, to predict and identify the likely environmental impacts of a planned project or development, including the detailed elaboration of alternatives.

Since EIA is intended for planned projects, it is not quite relevant for elimination of hot spots associated with accumulated environmental damage. The experience gained in this area may be in demand in the future while participating of the interested parties in evaluation of new project planned for construction.

### *Sampling and Analyses*

Sampling and analyses are essential elements in the assessment of contaminated site: it will determine the extent of soil contamination with environmental damage, and the precise boundaries of contaminated areas. In larger or more complex projects, there is often cause for relatively extensive sampling and monitoring to be conducted. This reduces the level of uncertainty and improves the basis for the risk assessment as well as the remediation option evaluation and selection processes. However, the extent of the sampling and monitoring should be determined based on the characteristics of the contaminated site or location: each site is different, so criteria that apply to one might not be applicable to another.

The following information should be documented in a sampling plan[7]: what substances to analyse for; sampling approach; sampling technique; number of samples; sampling vessel and volume; sample preservation; analytical technique; a plan for protective measures for environment and health of field workers at the site and for people living at the site or visiting the site.

The analyses should have correct detection limits, i.e. concentrations can be measured at as low levels as necessary for comparison with guideline values to assess the risk posed by the contamination. Comparisons with guideline values should be made using representative concentrations (based on measured concentrations in relevant media).

Russian regional and/or municipal environmental authorities are facing with difficulties while drafting sampling and analyses section of ToR for projects of accumulated damage due to lack of knowledge and absence of experienced staff. In some cases, description of sampling and analyses are based on commercial offers from laboratories. Thus, Nordic experience in sampling and analyses, in particular sampling approach, sampling technique, and analytical technique, is of the essence for appropriate Russian stakeholders (federal, regional and municipal environmental authorities, laboratories, academia and practitioners). Transfer of knowledge and application of modern sampling and analyses approaches and techniques will contribute to more efficient planning and drafting of remediation projects and achieve better project performance on reduction of negative environmental impact.

### *Environmental Risk Assessment*

Environmental risk assessment evaluates which risks a contaminated site constitutes, today and in the future, assigns magnitudes and probabilities to the adverse effects of contamination, and to what extent the contamination has to be reduced to, to not expose humans or the environment to unacceptable risks.

Methodology for risk assessment consists of the following main steps: a problem description including a conceptual model (describes how contaminants can spread from the site and affect human health, the environment and natural resources); exposure analysis; effect assessment; risk characterization. However, the individual steps should be adapted to incorporate all steps needed depending on the extent of the project.

The methodology is generally based on a tiered approach with increasing degree of complexity and detail. This tiered approach will ensure that simple cases can be completed relatively quickly with minimum resources while risk in more complex cases and potentially serious situations are completed with a greater use of resources[8]. Information can be gradually expanded to reduce the uncertainty and subsequently improve the rationale for decision to assess the need for action or remediation.

ERA is performed based on remediation goals and constitutes a tool for deciding whether to carry out corrective actions at the contaminated site and for setting the final remediation objective, thus selecting the best clean-up strategies.

In the context of Russian practices, risk assessment and risk-based management approach and their application under remediation process are lacking. ERA are an important component of an increasing number of environmental decisions. The results of these assessments help determine the need for and/or nature of remediation actions at contaminated sites by supporting the derivation of clean-up levels, assisting in development of  elimination of accumulated environmental damage and in permitting new facilities. As mentioned above, the first steps of raising awareness and training on risk-based management approaches to contaminated sites for Russian regional stakeholders have been taking during the recent under SHE Support Activity 2 in 2020-2021. Training was highly appreciated by participants. Further transfer of Nordic knowledge is essential to evaluate how current guidelines and approaches in the Nordic countries could be used as tools

[7] Compendium Remediation of Contaminated Sites in Sweden, Version 1, Swedish EPA, June 2021
[8] Guidelines for the Risk Assessment of Contaminated Sites, Norwegian Pollution Control Authority, 1999

to identify pros and cons in the corresponding Russian legislation and to introduce the key internationally accepted principals and procedures on risk assessment and risk-based management into Russian practices.

***Remediation Design and Remediation Plan***

Different types of contaminated have to be assessed in different ways to find the most suitable remediation options. The contaminant Remediation Design and Remediation Plan are an integral part of the contaminated site remediation process and is carried out to select the most appropriate remediation methods and techniques for each individual site in order to feasibly perform contamination clean-up actions over a strategic period of time and to achieve remediation goals.

*Remediation design* provides for remediation option analysis, evaluation and selection processes and includes: an overview of the remediation techniques and technologies to be employed; detailed information on each element and stage of the remediation plan; a detailed cost estimate. When it is clear which options of remediation are potential candidates, an initial analysis is used to filter out options that do not meet the remediation goals, are not technically feasible, or do not provide acceptable results.

To narrow down the choices to the best selection, a detailed evaluation, e.g. feasibility study, will compare the pros and cons of each remediation option with respect to costs, potential risks during and after implementation of the remediation options and possible disturbances that may occur. A remediation option may consist of several remediation methods, which in turn may include several different remediation techniques. Reviewing case studies or applying knowledge from past projects can be helpful in analysing the remediation options. If necessary, bench and field pilot tests can provide important site-specific information for remediation evaluation and design. *Cost-effectiveness* is an objective addressed by identifying remediation options that meet all remedial objectives for the least cost. In practice, not all remediation options meet all remediation objectives equally; therefore, the most cost-effective option is not necessarily the least cost alternative.

Remediation design shall mean those remediation design activities to be undertaken to develop the final plan and specifications for the remediation actions.

*Remediation plan* describes the preferred clean-up option and outlines the course of clean-up action for the site. Remediation plan outlines which remediation methods and techniques are necessary and why. Moreover, feasibility in terms of cost, time, and effort, is additionally a discussion point. Remediation plan also explain what other methods may be considerable. Lastly, each remediation plan discusses the site-specific objectives, with a focus on reasonable time frames, remediation goals, and case closure requirements. As soon as the remediation plan is approved, the implementation can begin.

The site conditions for each individual site heavily influence the selection of remediation method and techniques. The selection of the most effective remediation option is critical to the success of the project. Several Russian companies, operating in the environmental sector, have examples of successful implementation of projects on contaminated site remediation using best practices, incl. bioremediation techniques. However, these projects are sporadic and are mostly of a demonstration nature. The use of the BAT for contaminated site remediation is not well studied and tested, and is of limited use in North-West Russia.

Remediation of sites in northern environment poses unique challenges. Sites are inherently remote and may be difficult to access; it can require transportation of some equipment typically from hundreds of kilometers away and at great cost; climate restrictions (for example, cold temperatures and ice conditions) and short seasonal windows to conduct work may limit remediation options. The exchange of Nordic experience in testing and evaluation of BAT for contamination remediation is an important component of cooperation to promote active application of best practices in contaminated soil remediation projects in the Russian Barents region in future.

Analysis of the Nordic competence and technologies in contaminated site remediation points out necessity of study and further application of Nordic best environmental practices in soil remediation project in North-West Russia and highlights the need of knowledge transfer and exchange of information at almost all steps of contaminated site remediation process. This applies, in particular, to sample planning, environmental risk assessment and risk-based management approach, and technologies testing, remediation design and remediation plan. These are areas of special value for implementation in North-West Russia to contribute to the Russian sector's development.

# 6. SHORT ANALYSIS OF BARRIERS FOR NORDIC COMPANIES IN ENTERING TO THE RUSSIAN ARCTIC AND BARENTS REGION

This chapter presents short analysis of barriers (incl. administrative, technical, legal, financial, etc.) for Nordic companies and institutions in entering and operating in the Russian Arctic and Barents region.

When planning large-scale projects requiring the provision of a wide range of services and works, the use of goods and products, technical equipment and machinery, as well as projects with the participation of federal, regional, municipal authorities, it is necessary to consider possible limitations established by the Russian Federation in the framework of political and foreign economic activities. The list of the main normative and legal documents regulating contaminated soil remediation activities is presented in the Appendix 2.

Projects with participation of authorities, among which are the Barents hot spots and projects of accumulated environmental damage and landfills under the Clean Country Project, are subject to the current budgetary and governmental procurement legislation.

Thus, restrictions on the admission of certain types of import commodities for state and municipal procurement have been established (RF Government Resolution of 30.04.2021 No. 617). The Resolution includes a list of these goods.

There are also restrictions on the admission of import commodities and the provision of works and services by foreign persons for projects implemented in off-limits facility/area (RF Government Resolution of 30.04.2021 No. 616). To carry out work at these facilities, it is required to obtain a permit to enter the site. There are a number of exceptions for the purchase of import commodities: for example, for goods and equipment that are not manufactured in Russia, purchase of spare parts and consumables for existing equipment, etc.

The contract system in the sphere of purchasing goods, works, and services to provide state and municipal needs is regulated by Federal Law 44-FZ of 05.04.2013. According to budget legislation, projects implemented by the authorities cannot be implemented at the expense of foreign funds. In some cases, grant international financing can be attracted, if the recipient of the funds is a state or municipal company. In addition it is preferred that remuneration of local subcontractor services should be made directly to these companies.

Considering the import substitution policy pursued by Russia, the priority in procurement is given to Russian-made commodity goods.

Among the technical limitations, a number of requirements are also imposed on the performance of work and services, as well as on the goods and products. Companies, providing services or performing work, must be licensed for certain types of work in cases established by Russian legislation. If a foreign company participates in remediation measures, technical and biological, a license will be required. One of the terms to obtain a license is registration of a company in Russia, which is impractical for small-scale municipal projects. In this case, the participation of a foreign company in the project is most expedient as a consultant for Russian companies.

With regard to application of biological products, sorbents, mineral additives used in the bioremediation of contaminated soil, according to Russian legislation, it is allowed if they have: a) all permits for use, b) must be manufactured in accordance with the specifications and supplied with detailed application instructions, c) have permission for use in accordance with Russian legislation, etc. Thus, foreign biological products are not relevant for application in Russia. Foreign companies could take part as consultants in production and bench and/or field testing of biological products, carried out by Russian companies and institutes.

Most likely, the most advanced remediation methods may be subject to exception. However, their application in small-scale municipal projects can significantly increase the cost of the project in terms of assessing and testing the appropriate method and decrease cost-efficiency of the project.

Restrictions caused by legislation and norms limit the ability to implement international projects using Nordic experience and knowledge in full range. The most feasible are projects on transfer of knowledge, exchange of experience, training, and the provision of consulting services.

The knowledge and experience of Nordic consulting companies would be valuable in development of project documentation, required for project preparation: ToR, assessments, feasibility study, tender documentation, etc. However, it should be borne in mind that the Russian authorities are not allowed to finance the services of foreign consultants. Municipal companies or small commercial companies are not ready to take on any financial obligations unless they are participants of foreign economic activities. Therefore, remuneration of foreign consulting services should be provided by international financial sources.

When it comes to the application of the Nordic experience at the stage of “physical” works, the participation of Nordic companies is the most uncertain due to Russian restrictions. In this case, it would be advisable to consider the possibility of participating in specific tasks/activities, more important from the point of view of the Nordic experience application, at different project steps.

Despite the existing limitations, the application of the Nordic experience is an important support tool for projects in the Russian Barents region and the participation of Nordic companies is feasible. It will require identifying the form of services to be provided (training, consulting services, leasing of equipment, etc.) and appropriate financial mechanism for each specific project.

# 7. CONCLUSIONS AND RECOMMENDATIONS

### *Conclusions*

The study of relevant Nordic competence and capability for cleaning-up contaminated soil and remediating oil polluted sites aims to engage key Nordic competencies to contribute in improving the environmental status of the oil related hot spots in the Russian Barents region. This chapter presents findings and recommendations for further actions to help to remediate oil pollution in the Russian Barents region.

The analysis of the situation shows that remediation of land polluted with oil and oil products is an integral part of the process applied to contaminated site management and remediation in whole. The same contaminated site management and remediation approaches, remediation methods and techniques are used both to contaminated land and to land contaminated with oil products. Therefore, this study on the relevant Nordic competence and technologies for remediation of oil polluted land was carried out in the context of contaminated soil remediation in general. This make it possible to get a better overview of the situation on addressing soil contamination and oil pollution remediation issues in the Nordic countries.

Soil can be contaminated by activities where harmful substances (chemicals) or wastes are used, manufactured, processed, transported or stored. Contamination can be caused either by a single accident, or by long-term emissions stemming from normal activities, or happened decades ago.

In most cases, traditional ex situ remediation is continues to be used and is preferable, as it is a quick and efficient way to achieve the action requirements. The cost of remediation has generally been the primary criterion for deciding upon remediation actions. The size of the contaminated area, the availability of remediation material, and the solutions for treatment of soil and ground water will strongly influence the costs. Nevertheless, many times an alternative methods can be more cost-effective and better from an environmental point of view.

As the experience on elimination of contamination and/or oil pollution shows, the nature of pollution is different from area to area. The same advanced biological methods may at some sites contribute to effective remediation and the creation of conditions favorable for further self-restoration of lands, while at others they may not be effective and fail to achieve the expected results.

The application of best Nordic practices in regards to approaches on management and clean-up of contaminated soil provides an opportunity to evaluate different remediation alternatives and select the most cost-effective methods to ensure that remediation goals are achieved.

Recommendations are formulated based on the study of relevant Nordic competence and technologies for contaminated soil remediation and analysis of barriers for Nordic companies in entering to the Russian Barents region and described below.

### *Recommendations*

Based on the needs of Russian stakeholders, the priority areas includes knowledge transfer and exchange of experience in environmental risk assessment and risk-based management approach, sample planning, technologies testing, remediation design and remediation action plan and the following measures are proposed.

- *Publications*
  The data and methods obtained from various in situ treatments, implemented in the field, should be collected and published in a form available for everyone. Increased knowledge of both workable practices and more challenging, unworkable methods would benefit the parties acting in the field of soil restoration and would possibly encourage the use of in situ remediation methods more.

- *Barents Database*
  In the aim of improving remediation technologies, experiences and results from completed projects have to be understood, compared, and shared. However, such information is not always available, rarely published in scientific journals, and often only published in a national language. As a first step, a common database and/or website for the Nordic/Barents countries containing information on the success of completed and ongoing soil remediation projects could be a useful resource for future remediation actions. (As an example, database could include some elements of the Danish Soil Partnership remediation catalogue https://www.danishsoil.org/afvaergekatalog.php, but it should be developed further according to the needs of the stakeholders).

A series of targeted training courses maybe carried out upon request of Russian stakeholders:

- *Environmental sampling planning*
  The training addresses the preparatory activities for a contaminated site assessment project before the field campaign begins. This training should include an introduction to environmental sampling planning and sampling strategies, hands-on sampling best practices, their respective limitations and challenges, case studies and examples of sampling tools and techniques. It should also provide key issues encountered during implementation of field activities, including use of field monitoring instruments, quality assurance, operating procedures for the field sampling campaign.

- *Environmental Risk Assessment and Risk-Based Management Approach*
  The training aims to strengthening the capacity of local stakeholders on contaminated site risk assessment to characterize and evaluate the risks from oil pollution hot spots. The training will provide an overview of the international best practices on contaminated site risk assessments and risk-based management approach and discuss some of the practical challenges that practitioners typically face in carrying-out such work. The training should address economic valuation of environmental damage from oil spills and detailed quantitative risk assessment to derive site specific assessment criteria that are representative of local conditions. The training could also include group exercises and field visit to carry out a rapid site assessment and develop a conceptual site model of contaminated site.

- *Bioremediation Techniques Testing*
  The training aims to strengthen the capacity of the Russian stakeholders on remediating oil contaminated sites. It is suggested, that most common best practices on bioremediation techniques are introduced and discussed, emphasizing the potential role of bioremediation given its applicability and cost-effectiveness in the context of national and local capacities and resources. The workshop should be based on a 'learning by doing approach' and involve field trail, e.g. setting-up a practical bioremediation demonstration trial, which could include practical demonstration of the different steps in setting up a bioremediation cell, and etc. One or more hot spot sites can be selected for the demonstration purpose.

- *Remediation Design and Remediation Plan*
  The training course is offered to enhance local capacities for improved environmental management and to assist implementing cost-effective clean-up of oil contaminated sites. This training could follow the training on Bioremediation Techniques Testing and should provided an overview of the different methods and techniques (physical, thermal and bioremediation) for remediation of oil contaminated sites. The design and implementation of a tiered remediation design and remediation plan based on risk and remediation goals criteria should be examined.

The recommended activities will allow acquiring an understanding of the important challenges and strengthening capacity of local authorities and practitioners to conduct contaminated site assessments and remediation in a proper and timely manner on par with international best practices. Training courses need to be tailored to well identified groups such as field staff, project managers, those involved in environmental risk assessments.

# ANNEX 1: THE LIST OF NORDIC COMPANIES AND INSTITUTIONS DEALING WITH OIL POLLUTION ISSUES

**International companies: head office is highlighted by turquoise*

| Name | | Type of operation | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Works in countries | Oil remediation | ESA | Soil remediation | Sampling | Testing /Laboratory | Equipment | Other |
| **INTERNATIONAL COMPANIES** | | | | | | | | |
| **AFRY** (ÅF Pöyry) https://afry.com | Offices in Denmark, Austria, Canada, China, Germany, Hungary, Italy, Poland, Switzerland, projects - worldwide | | | | | | | |
| **AFRY AB** https://afry.com/sv<br>Frösundaleden 2A, 169 75 Solna<br>T: +46 10 505 00 00, E: info@afry.com | Sweden | X | X | X | | | | Land, groundwater and buildings. |
| **AFRY Oy** https://afry.com/fi-fi<br>Jaakonkatu 3, 01620 Vantaa<br>T: + 358 10 3311, E: info.fi@afry.com | Finland | X | X | X | X | | | Environmental Due Diligence (EDD), remediation monitoring, ERA. Geophysical measurements |
| **AFRY AS** https://afry.com/no-no<br>Lilleakerveien 8, 0283 Oslo<br>T: +47 24 10 10 10, E: info.no@afry.com | Norway | | X | | | | | |
| **ATKINS (SNC-Lavalin Group, CAN)** www.snclavalin.com | Offices and projects in UK, America, Middle East, Africa, Asia Pacific, Europe. Atkins is member of SNC-Lavalin group, has head office in UK. | | | | | | | |
| **ATKINS Sweden AB** https://atkins.se<br>Västgötagatan 5, 118 27 Stockholm<br>T: +46 8 563 006 00, E: info-se@atkinsglobal.com | Sweden | X | X | X | | | | Investigations, ERA, ESA, risk assessment, design, inspection. |
| **ATKINS Denmark A/S** https://atkins.dk<br>Arne Jacobsens Allé 17, 2300 København<br>T: + +45 52 51 90 00, E: info-dk@atkinsglobal.com | International + Denmark | X | X | X | X | | X | Have some equipment for remediation, sometimes use subcontractors as well. |
| **COWI** www.cowi.com | Offices and projects in Europe, Africa, North America, the Gulf, Asia | | | | | | | |
| **COWI AB** www.cowi.se<br>Skärgårdsgatan 1, SE-414 58 Göteborg<br>Te.l: +46 (0)10 850 10 00, E: info@cowi.se | Sweden | X | X | X | | | | |
| **COWI AS** www.cowi.no<br>Karvesvingen 2, 0579 Oslo<br>Tel.: +47 2266 0980, E: firmapost@cowi.no | Norway | X | X | X | | | | |
| **COWI A/S** www.cowi.dk<br>Parallelvej 2, 2800 Kongens Lyngby | Denmark | X | X | X | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T: +45 56 40 00 00, E: cowi@cowi.com | | | | | | | | |
| **GOLDER / WSP group** (CAN) www.golder.com | Offices in Europe, America, Asia Pacific, Africa | | | | | | | |
| **Golder Associates AB** www.golder.com<br>Östgötagatan 12, 116 25 Stockholm<br>T: +46 8 506 306 00, E: officemanager@golder.se | Sweden | X | X | X | | | | |
| **Golder Associates Oy** www.golder.com<br>Konalantie 47 B, 00390, Helsinki<br>T: +358 9 561 7210, E: ville_malmivaara@golder.fi | Finland | X | X | X | | | | |
| **Golder Associates AS** www.golder.com<br>Ilebergveien 3, 3011 Drammen<br>T: +47 32 85 07 71, E: sivellen.paule@golder.no | Norway | X | X | X | X | | | |
| **Golder Associates A/S** www.golder.com<br>Linnés Allé 2, 2630 Taastrup<br>T: +45 70 27 47 57, E: mthorman@golder.com | Denmark | X | X | X | | | | |
| **NIRAS** www.niras.com | Offices and projects in Europe, CIS countries – TJK, UKR, GEO, Asia, Africa, America, Australia | | | | | | | |
| **NIRAS Sweden AB** https://www.niras.se<br>Hantverkargatan 11B, 112 21 Stockholm<br>T: +46 85 038 44 00, E: info@niras.se | Sweden | X | X | X | X | | | Investigations, risk assessments, measures' plan. |
| **NIRAS Norway AS** https://www.nirasnorge.no<br>Kongens gate 4, 0153 Oslo<br>T: +47 22 06 65 00, E: norgeadmin@niras.com | Norway | X | X | X | | | | Environmental survey, remediation description.<br>Oil separators – water treatment |
| **NIRAS A/S** https://www.niras.com<br>Sortemosevej 19, DK - 3450 Allerød<br>T: +45 48104200, E: niras@niras.com | Denmark | X | X | X | X | X | | |
| **NORCONSULT** www.norconsult.com | Projects in Europe, South America, southern Africa and South-East Asia | | | | | | | |
| **Norconsult AB** www.norconsult.se<br>Theres Svenssons gata 11, 417 55 Göteborg<br>T: +46 10 141 80 00, E: mail@norconsult.com | Sweden | X | X | X | X | | | Action plan, design of measures, risk assessment. |
| **Norconsult AS** www.norconsult.no<br>Vestfjordgaten 4, 1338, Sandvika<br>T: +47 67 57 10 00, E: firmapost@norconsult.com | Norway | X | X | X | | | | Action plan, cost assessment, design of measures |
| **Norconsult A/S** www.norconsult.dk<br>Herlev Bygade 14, 2730 Herlev<br>T: +45 4488 2000, E: norconsultdk@norconsult.com | Denmark | X | X | X | | | | |
| **RAMBOLL** https://ramboll.com | Offices in Europe, America, Australia, Middle East and Asia Pacific, Southern Africa | | | | | | | |
| **Ramboll Sweden AB** https://se.ramboll.com<br>Krukmakargatan 21, 104 62 Stockholm | Sweden | X | X | X | X | | | Design of measures, supervision of remediation works |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T:+46 10 615 60 00, E: infosverige@ramboll.se | | | | | | | | |
| **Ramboll Finland Oy** https://fi.ramboll.com<br>PO Box 25, Itsehallintokuja 3, FI-02601 Espoo<br>T: +358 20 755 611, E: info@ramboll.fi | Finland | X | X | X | X | | | Supervision of remediation works. Methods development- STSO |
| **Ramboll Norway AS** https://no.ramboll.com<br>Harbitzalléen 5, 0275 Oslo<br>T: +47 22 51 80 00, E: firmapost@ramboll.no | Norway | X | X | X | X | | | Measurements, design of measures, risk assessment. Methods development - biological treatment, STSO. |
| **Ramboll Denmark A/S** https://dk.ramboll.com<br>Hannemanns Allé 53, DK-2300 København S<br>T:+45 5161 1000, E: info@ramboll.dk | Denmark | X | X | X | X | X | | |
| **RGS N0RDIC** www.rgsnordic.com | Denmark, Sweden, Norway (only water treatment) | | | | | | | |
| **RGS Nordic AB** www.rgsnordic.com/se<br>Östra Sörredsvägen 40, 418 78 Göteborg<br>T: +46 771 48 90 90, E: info@rgsnordic.com | Sweden | X | X | X | X | X | | Approved landfill for polluted soil. Soil treatment plant, GW treatment, Oil remediation at their sites - physical, biological, chemical, and thermal methods (ex-situ always) |
| **RGS Nordic A/S** www.rgsnordic.com<br>Selinevej 4, 2300 København<br>T: +45 88 77 90 90, E: cse@rgsnordic.com | Denmark | X | X | X | X | | | |
| **SWECO** www.swecogroup.com | Projects in 70 countries | | | | | | | |
| **Sweco Sverige AB** www.sweco.se<br>Gjörwellsgatan 22, 112 60 Stockholm<br>T: +46 8 695 60 00, E: | Sweden | X | X | X | X | | | Oil emergency service. Design of measures. |
| **Sweco Norge AS** www.sweco.no<br>Drammensveien 260, 0283 Oslo<br>T: +47 67 12 80 00, E: post@sweco.no | Norway | X | X | X | | | | |
| **Sweco Danmark A/S** www.sweco.dk<br>Ørestads Boulevard 41, 2300 København S<br>T: +45 7220 7207, E: info@sweco.dk | Denmark | X | X | X | X | | | |
| **WSP** (CAN) www.wsp.com | Offices in Europe, America, Asia, Africa, Middle East, Oceania | | | | | | | |
| **WSP Sverige** www.wsp.com/sv-SE<br>Arenavägen 7, 121 88, Stockholm<br>T: +46 10 722 50 00, E: n/a | Sweden | X | X | X | | | | |
| **WSP Finland Oy** www.wsp.com/fi-FI<br>Pasila station square 1, Fi-00520, Helsinki<br>T: +358 20 786 411, E: n/a | Finland | X | X | X | X | X | | Laboratiry in Oulu |
| **WSP Norge AS** www.wsp.com/nb-NO<br>Fred Olsens gate 1, 0152 Oslo<br>T: +47 93 24 00 00, E: n/a | Norway | X | X | X | X | | | |
| **WSP Denmark A/S** www.wsp.com/da-DK<br>Linnés Allé 2, 2630 Taastrup | Denmark | X | X | X | X | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T: +45 44 85 86 87, E: info-dk@wsp.com | | | | | | | | |
| **EUROFINS** www.eurofins.com | Offices in Europe, Asia, America, Africa, CIS countries - RUS, UKR, AZE, KAZ | | | | | | | |
| **Eurofins Environment Sweden AB** www.eurofins.se<br>Sjöhagsgatan 3, port 1, SE-531 40, Lidköping<br>T: +46 104 908 110, E: info.environment@eurofins.se | Sweden | X | | | | X | | |
| **Eurofins Environment Testing Oy** www.eurofins.fi<br>Pihlajamäentie 2, 00790 Helsinki<br>T: +358 40 7199010, E: myynti@eurofins.fi | Finland | X | X | | X | X | | Sampling, testing, measurements and monitoring. |
| **Eurofins Environment Testing Norway AS**<br>www.eurofins.no<br>Hoffsveien 13, 0275 Oslo<br>T: +47 945 04 260, E: miljo@eurofins.no | Norway | X | | | | X | | |
| **Eurofins Miljø A/S** www.eurofins.dk<br>Smedeskovvej 38, DK - 8464, Galten<br>T: +45 70 22 42 66, E: miljo@eurofins.dk | Denmark | X | | | | X | | |
| **ALS** www.alsglobal.com | Offices in America, Europe, Asia-Pacific, Africa & Middle East | | | | | | | |
| **ALS Scandinavia** www.alsglobal.se<br>Rinkebyvägen 19c, 182 36 Danderyd,<br>T: +46 8 527 752 00, E: info.ta@alsglobal.com | Sweden | X | | | X | X | | Environmental/chemical analyzes. |
| **ALS Finland Oy** www.alsglobal.fi<br>Ruosilankuja 3A, FIN-00390, Helsinki<br>T: +358 10 4701200, E: | Finland | X | | | | X | | Receipt of samples, reporting.<br>Is part of ALS Scandinavia. |
| **ALS Laboratory Group Norway AS** www.alsglobal.no<br>Drammensveien 264, 0283 Oslo<br>T: +47 22 13 18 00, E: info.on@alsglobal.com | Norway | X | | | | X | | Testing and analysis services. |
| **ALS Denmark A/S** www.alsglobal.dk<br>Bakkegårdsvej 406 A, 3050 Humlebæk<br>T: +45 49 25 07 70, E: info.hmb@alsglobal.com | Denmark | X | | | | X | | Microbiological and chemical analyzes. |
| **SWEDISH COMPANIES** | | | | | | | | |
| **Breccia Konsult AB** www.breccia.se<br>Blekingsborgsgatan 18, 214 63 Malmö<br>T: +46 70 944 11 27, E: cecilia@breccia.se | Sweden | | X | X | X | | | Contaminated land, groundwater, buildings |
| **DGE Sweden AB** www.dge.se<br>Norra Långgatan 1, SE-391 23 Kalmar<br>T: +46 10 200 80 82, E: info@dge.se | Sweden | X | X | X | X | | | All range of services of the project life cycle. |
| **Empirikon Konsult AB** www.empirikon.se<br>Smidesvägen 5, 186 36 Vallentuna<br>T: +46 85 1173310, E: info@empirikon.se | Sweden | X | X | X | X | | | Wide and long-term experience |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **EnviFix AB** http://envifix.se<br>Smörslottsgatan 38, 416 78 Gothenburg<br>T: +46 70 467 81 43, E: info@envifix.se | Sweden | X | X | | | | | Manager of several portals – survey, actions, methods |
| **Enviro Miljöteknik AB** http://enviromiljoteknik.se<br>Sätersfors 12, 566 91 Habo<br>T: +46 70 693 00 56, E: hanna@enviromiljoteknik.se | Sweden | X | X | X | X | | | Specializing in contaminated land and buildings |
| **Frigeo AB**<br>Smedjegatan 19, 972 32 Luleå<br>T: +46 70 571 00 65 | Kiruna<br>Luleå | | | | | | | Site is not available |
| **Geoveta AB** www.geoveta.se<br>Sjöängsvägen 2, 192 72 Sollentuna<br>T: +46 8 410 112 60, E: info@geoveta.se | Sweden<br>Kiruna | X | X | X | X | | X | |
| **Jordnära Miljökonsult AB** https://jordnaramiljo.se<br>Hamngatan 3, 531 34 Lidköping<br>T: +46 10 75 00 555, E: info@jordnaramiljo.se | Sweden | X | X | | X | | | |
| **Liljemark Consulting AB** www.liljemark.net<br>Jämtlandsgatan 151 B, 162 60 Vällingby,<br>T: +46 8-22 52 00, E: info@liljemark.net | Sweden | X | X | X | X | | | |
| **SAO Environmental Consulting AB** www.saoec.se<br>Möllegårdsvägen 67, 271 57 Ystad<br>T: +46 72 223 65 69, E: joe@saoec.se | Sweden | | X | X | | | | Contaminated sediments in freshwater and marine environments |
| **SGI** (Swedish Geotechnical Institute) www.sgi.se<br>Olaus Magnus Väg 35, SE-581 93 Linköping<br>T +46 13 20 18 00, E: sgi@swedgeo.se | Sweden | X | X | X | | X | | Also organize courses and seminars |
| **SGU (Geological Survey of Sweden)** https://sgu.se<br>Villavägen 18, Uppsala<br>T: +46 18 17 90 00, E: kundservice@sgu.se | Sweden<br>Luleå | X | X | X | | | | Surveys and measures in contaminated areas. |
| **Svevia AB** www.svevia.se<br>Fleminggatan 20, 112 26 Stockholm<br>T: +46 8 404 10 00, E: info@svevia.se | Sweden<br>Luleå<br>Piteå | X | X | X | X | X | X | A leader in soil remediation + treatment on site or at facilities. Has reception facilities for polluted masses. |
| **Swerock AB** https://swerock.se<br>Grustagsgatan 35, Helsingborg, Skane<br>T: +46 431 44 96 30, E: n/a | Sweden<br>Boden | X | X | X | | | X | Environmental services – recycling and soil remediation |
| **Tyrens AB** www.tyrens.se<br>Peter Myndes Backe 16, 118 86 Stockholm<br>Tel: +46 10 452 20 00, E: n/a | Sweden<br>Lithuania<br>Estonia<br>Poland | | X | X | | | | Offices in Kiruna, Luleå, Lund, Piteå, Umeå |
| **Wescon Miljökonsult AB** www.wescon.se<br>Norra Källgatan 22, 722 11 Västerås | Sweden | X | X | X | | | | |

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|---|---|---|---|---|---|---|---|---|
| T: +46 70 652 50 36 E: info@wescon.se | | | | | | | | |
| **IVL Swedish Environmental Research Institute**<br>www.ivl.se<br>Valhallavägen 81, 114 28 Stockholm<br>T: +46 10 788 65 00, E: n/a | Sweden<br>China<br>India, other | X | X | | X | X | | Acute assessments. Design of measures |
| **Dåva DAC** https://avfallscenter.se<br>Dåva Energiväg 10, 905 95 Umeå<br>T: +46 90 16 15 15 E: info@avfallscenter.se | Sweden | X | | | | X | X | Landfill and waste center for non-recycled or non-reused hazardous and non-hazardous wastes, soil.<br>Treatment technologies. |
| **EWGroup AB** https://ewgroup.se<br>Norra Oskarsgatan 19, 582 73 Linköping<br>T: +46 10 188 66 60, E: info@ewgroup.se | Sweden | X | | X | X | | X | Waste management, soil remediation, sampling and water treatment.<br>Own and partners disposal and treatment facilities. |
| **Geoserve AB** www.geoserve.se<br>Prästgårdsgatan 24, 431 44 Mölndal<br>T: +46 10 330 30 12, E: info@geoserve.se | Sweden | X | | X | X | | X | Cleaning and restoring from dry cleaners and petrol stations to oil depots and large industrial areas.<br>Use in situ and ex situ technologies. |
| **Nordic BioEngineering AB**<br>www.nordicbioengineering.com<br>Bredgränd 2, 111 30 Stockholm<br>T: +46 70 691 33 33, E: erik@nordicbioengineering.com | Sweden | X | | X | | | X | In situ bioremediation of oil contaminated land and water using microbes from the domain archaea. |
| **Recirk** www.recirk.se<br>284 22 Perstorp<br>T: +46 70 661 05 93, E: info@recirk.se | Sweden | X | | X | | | X | Implements and leases of components and systems for remediation of contaminated soil and ground water |
| **Lund University,** www.lunduniversity.lu.se | SE, International | X | X | X | X | X | | |
| **FINLANISH COMPANIES** | | | | | | | | |
| **Co-op Bionautit** www.bionautit.fi<br>Viikinkaari 9, 00790 Helsinki<br>T: +358 40 837 6812, E: leena.rasanen@bionautit.fi | Finland | X | | | X | X | | Microbiology, molecular biology. Research. Develops test packages. Organises training and workshops |
| **Doranova** www.doranova.fi<br>Valkkistentie 2, 37470 Vesilahti<br>T: 358 3 3143 1111, E: doranova@doranova.fi | China<br>Baltic region | X | X | X | | | X | Develops modular and remotely controllable soil and groundwater remediation unit |
| **Environmental Consulting Niemeläinen Oy**<br>https://www.ykn.fi<br>Kaukaankatu 23, 53200 Lappeenranta<br>T: +358 50 341 8684, E: timo.niemelainen@ykn.fi | Finland | X | X | X | | | | Provides consulting services to companies, communities and individuals. |
| **FCG Finnish Consulting Group Oy** www.fcg.fi<br>Osmontie 34, 00610 Helsinki<br>Tel +358 10 4090, E: n/a | Russia, Asia, Europe, Africa, Latin America, Oceania | | X | | | | | EIA, reports related to BAT decisions, permits.<br>Office in Oulu. |

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| **Lamor Corporation Oy** www.lamor.com<br>Rihkamatori 2, 06100 Porvoo<br>T: +358 20 765 0100, E: info@lamor.com | Russia, Asia, Africa, South America, USA | X | X | X | | | X | Has experience in Russia and Arctic. Oil spill response, waste management, soil and water treatment. Experience on remediation of large sites abroad. |
| **Nordic Envicon Oy** www.nordicenvicon.fi<br>Huopalahdentie 24, 00350 Helsinki<br>T: +358 40 048 9361, E: mikko.kotro@nordicenvicon.fi | Finland | X | X | X | | | | In situ or on site technologies |
| **Remsoil Oy** https://remsoil.com<br>Santastentie 197, 38950 Honkajoki<br>T: +358 50 0890 292, E: jan.hainari-maula@remsoil.com | Finland | X | X | X | X | | X | REMSOIL® soil bioremediation method. Environmental management and biotechnology. |
| **Vahanen Environment Oy** https://vahanen.com<br>Linnoitustie 5, 02600 Espoo<br>T: +358 20 7698 698, E: firstname.lastname@vahanen.com | Finland<br>Estonia,<br>Romania | X | X | X | | | | Experience from NCM projects |
| **MetropoliLab Oy** www.metropolilab.fi<br>Viikinkaari 4, Cultivator II, 00790 Helsinki<br>T: +358 10 391 350, E: metropolilab@metropolilab.fi | Finland | | | | X | X | | Services includes sample taking and sample transportation, in situ measurements. |
| **SGS Finland Oy** www.sgs.fi<br>Takomotie 8, 00380, Helsinki<br>T: +358 9 6963 701, E: n/a | over 2600 offices world-wide, incl. RF | X | | | | X | | Testing, inspection and certification, training. |
| **Ekogrid Oy** (Eko Harden Technologies)<br>https://ekogrid.fi<br>Hiomotie 10, 00380 Helsinki<br>T: +358 20 743 2670, E: n/a | Nordic states, Turkey, China, Nigeria, Canada, USA, Latin America | X | | | | | X | Develops and provides technologies for soil, groundwater and sediment remediation |
| **EngWater Oy** https://engwater.fi<br>Vanha Kormuntie 40, 11710 Riihimäki<br>T: +358 505 769 219, E: antti.seppala@engwater.fi | Finland | X | | | | | X | Water treatment. In situ soil and water remediation. Experience from Russia. |
| **Savaterra Oy** https://savaterra.fi<br>Ahjotie 23, 96300 Rovaniemi<br>T. +358 400 322 344, E: savaterra@savaterra.fi | Baltic states, CIS area, China, Africa | X | | | | | X | Thermal desorption soil treatment. Soil treatment facilities. Liquid oily waste treatment and recycling plant. Website in Russian. |
| **University of Helsinki,** www.helsinki.fi/en | FI, International | X | X | X | X | X | | |
| **Uppsala University,** www.uu.se/en | FI, International | X | X | X | X | X | | |
| **NORWEGIAN COMPANIES** | | | | | | | | |
| **Akvaplan-niva AS** www.akvaplan.niva.no<br>Hjalmar Johansens gate 14, 9007 Tromsø<br>T: +47 77 75 03 00, E: info@akvaplan.niva.no | Norway<br>Russia | X | X | | X | X | | Experience from Russia and Arctic region. ESA, EIA, monitoring, R&D, analytical services, technical inspections. |
| **DMR miljø og geoteknikk AS** www.dmr.as<br>Maridalsveien 163, N-0461 Oslo<br>T: +47 22 12 02 03, E: dmr@dmr.as | Norway | X | X | X | X | | | All range of services of project cycle. |

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| **GrunnTeknikk AS** www.grunnteknikk.no<br>Åslyveien 15, 3170 Sem<br>T: +47 459 04 500, E: post@grunnteknikk.no | Norway | | X | X | | | | Geotechnics and environmental geology. Environmental technical investigations, risk assessments, action plans |
| **Miljøvakta AS** https://miljovakta.no<br>Tuenveien 84, 2000 Lillestrøm<br>T: +47 23 89 72 52, E: post@miljovakta.no | Norway<br>Tromsø | X | X | | X | | X | Clean-up of acute oil pollution. Environmental technical survey. Mobile treatment plants and ADR sludge extractors. |
| **MOE AS** www.moe-as.no<br>Vollsveien 17A, 1366 Lysaker<br>T: +47 6698 9510, E: info@moe-as.no | Norway | X | X | X | | | | Management of contaminated soil and groundwater for construction and demolition projects |
| **Multiconsult AS** www.multiconsult.no<br>Nedre Skøyen vei 2, 0276 Oslo<br>T: +47 21 58 50 00, E: oslo@multiconsult.no | Norway,<br>UK, Poland, Kenya, Zambia, Thailand | X | X | X | X | | | Has worldwide experience. Services from studies to design, O&M, to decontamination and demolition. |
| **NIVA** (Norwegian Institute for Water Research)<br>www.niva.no<br>Økernveien 94, 0579 Oslo<br>Tel: +47 22 18 51 00, E: post@niva.no | Norway,<br>International | | X | | | X | | Water and sediments. Mapping, EIA, clean-up measures, monitoring.<br>Experience from Arctic regions |
| **SINTEF** www.sintef.no<br>Strindvegen 4, Trondheim<br>T: +47 40 00 51 00, E: n/a | Norway,<br>Belgium | X | X | | | X | | One of Europe's largest research organizations. Experience from Arctic region. |
| **Sea Eco AS** www.sea-eco.com<br>Hamneveien 5, 9455 Engenes<br>T: +47 913 30 130, E: post@sea-eco.no | Norway | X | X | X | X | | | Innovative R&D projects, environmental consultancy and environmental surveys. |
| **NGI** (Norwegian Geotechnical Institute) www.ngi.no<br>Sognsveien 72, N-0855 Oslo<br>T: +47 22 02 30 00, E: ngi@ngi.no | Norway | X | X | X | X | X | | Acute pollution and decontamination of oil pollution |
| **Labora AS** https://labora.no<br>Klinkerveien 8, 8006 Bodø<br>T: +47 75 56 63 00, E: firmapost@labora.no | Norway<br>Tromsø | X | | | | X | | |
| **AquaBlok Norge AS** www.aquablok.com<br>Dåpaløkka 56, 3231 Sandefjord<br>T: +47 901 37 582, E: n/a | Norway, USA,<br>Canada, Australia | X | | | | X | X | Composite materials manufacturer. Remediation and geotechnical sealing solutions. Lab and technical support. |
| **Lindum AS** https://lindum.no<br>Lerpeveien 155, 3036 Drammen<br>T: +47 32 21 09 00, E: post@lindum.no | Norway | X | | | | | X | Treatment and disposal of contaminated masses at own facilities. Biological treatment of oil contaminated masses. |
| **Miljøteknikk Terrateam AS** www.terrateam.no<br>Tungtransportveien 19, 8626 Mo i Rana<br>T: +47 75 14 49 50, E: miljoteknikk@terrateam.no | | X | | | | X | X | Treatment and disposal of contaminated masses and oil contaminated soil |

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| **NOAH AS** https://noah.no<br>Stranden 11, 0250 Oslo<br>T: +47 33 09 95 00, E: post@noah.no | Norway, Denmark, Sweden | | | | | | X | Chemical treatment. Treatment of hazardous waste and contaminated excavation waste. Approved landfill for polluted soil. |
| **University of Oslo, UiO,** www.uio.no | NO, International | X | X | X | X | X | | |
| **UiT The Arctic University of Norway,** https://en.uit.no | NO, International | X | X | X | X | X | | |
| **University of Stavanger, UiS,** www.uis.no | NO, International | X | X | X | X | X | | |
| **DANISH COMPANIES** | | | | | | | | |
| **Aktor Innovation ApS** www.aktor.dk<br>Engsvinget 34, 2400 Copenhagen<br>T: +45 57 80 70 60, E-mail: aktor@aktor.dk | Denmark | X | X | X | | | | |
| **Arkil Fundering A/S** https://www.arkil.dk<br>Søndergård Alle 4, 6500 Vojens<br>T: +45 73 22 50 50, E: arkil@arkil.dk | International (40%, mainly Europe), Denmark 60% | X | | X | | | X | Environmental treatment. Has done a lot of remediation – subcontractors to the consultancy companies. |
| **BioRem ApS** www.biorem.dk<br>Hvedemarken 6, DK-8520 Lystrup<br>T: +45 86 74 2266, E: info@biorem.dk | Denmark | X | X | X | | | | Biological treatment. |
| **DGE Miljø- og Ingeniørfirma A/S** www.dge.dk<br>Jelshøjvænget 11, 8270 Højbjerg<br>T: +45 7010 3400, E: dge@dge.dk | Denmark, Norway, Finland, Lithuania, Estonia | X | X | X | | | | Acute environmental service, pollution study, land recycling, soil management, purification of contaminated soil. |
| **DMR A/S** https://www.dmr.dk<br>Hårup Østervej 3, DK-8600 Silkeborg<br>T: +45 86 95 06 55, E: dmr@dmr.dk | Denmark, Norway | X | X | X | | | | All range of services of project cycle. |
| **EKJ rådgivende ingeniører A/S** www.ekj.dk<br>Blegdamsvej 58, 2100 Copenhagen<br>T: +45 33 11 14 14, E: info@ekj.dk | Denmark | X | X | X | | | | |
| **Geo A/S** www.geo.dk<br>Maglebjergvej 1, 2800 Kgs. Lyngby<br>T: +45 4588 4444, E: geo@geo.dk | Denmark | X | X | X | X | | X | They have some equipment for remediation - especially ground water |
| **GeoMiljø A/S** https://geomiljo.dk<br>Tornebakke 3, 3550 Slangerup,<br>T: +45 70 22 33 30, E: cbs@geomiljo.dk | Denmark | | X | X | X | | | |
| **GEUS** (Geological Survey of Denmark and Greenland) www.geus.dk<br>Øster Voldgade 10, 1350 Copenhagen<br>T: +45 38 14 20 00, E: geus@geus.dk | Denmark, Greenland | | | X | | | | Develop methods both for characterizing contaminants and for cleaning-up contaminants on site. |
| **Jord Miljø A/S** https://jordmiljo.dk<br>Borupvang 5E, 2750 Ballerup<br>T: +45 35 82 04 02, E: jordmil@jordmil.dk | Denmark | X | X | X | X | | | |

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| **Krüger-Veolia A/S** www.kruger.dk<br>Gladsaxevej 363, 2860 Søborg<br>T: +45 3969 0222, E: kruger@kruger.dk | Denmark, Internatonal | X | | X | | X | X | In-situ soil and groundwater purification.<br>Thermal soil remediation.<br>Has experience in Russia. |
| **MOE A/S** www.moe.dk<br>Buddingevej 272, 2860 Søborg<br>T: +45 4457 6000, E: info@moe.dk | Denmark, Norway, Philippines | X | X | X | X | | | Management of contaminated soil and groundwater for construction and demolition projects |
| **MT Højgaard A/S** https://mth.dk<br>Knud Højgaards Vej 7, 2860 Søborg<br>T: +45 70 12 24 00, E: info-mthint@mth.dk | Denmark, Sweden, Greenland, Faroe Islands, Maldives, Portugal, Africa | X | | X | | | | |
| **Nordiq Group A/S** www.nordiq-group.dk<br>Bygmestervej 59, 2400 Copenhagen<br>T: +45 31 145 145, E: info@nordiq-group.dk | Denmark | X | X | X | | | | |
| **Højvang Laboratorier A/S** https://hmlab.dk<br>Industri Vest 8, 4293 Dianalund<br>T: +45 5824 2458, E-mail: hmlab@hmlab.dk | Denmark | X | | | | X | | |
| **BHC Miljø A/S** www.bhc-as.dk<br>Foldager 5, 6400 Sønderborg<br>T: +45 7449 1209, E: bhc@bhc-as.dk | Denmark | X | | | | | X | Equipment, heavy machinery, transport and receiving facilities. |
| **Boregruppen A/S** https://boregruppen.dk<br>Rørgangen 2, 2690 Karlslunde<br>T: +45 6611 0618, E: info@boregruppen.dk | Denmark | X | | | X | | X | Soil survey, testing, drilling services, relocation of land. |
| **Ejlskov A/S** https://ejlskov.com<br>Jens Olsens Vej 3, DK-8200 Aarhus<br>T: +45 87 31 00 60, E: n/a | Denmark, China | X | | | | | X | Biological remediation, planning and implementation of clean-up. |
| **GeoConsult ApS** https://www.gec.dk<br>Snedkervej 39, 6740 Bramming<br>T: +45 75 10 27 77, E: info@gec.dk | Denmark | | | | | X | X | Excavation and drilling equipment. Soil surveys, environmental studies. |
| **Jordrens Syd ApS** https://jordrenssyd.dk<br>Flensburg Landevej 1, Søgaard, 6200 Aabenraa<br>T: +45 73 68 00 03, E: jord@jordrenssyd.dk | Denmark | X | | | | | X | Remediation and receiving facilities. |
| **Jysk Geoteknik A/S** www.jyskgeoteknik.dk<br>Sallingsundvej 4, 6715 Esbjerg N<br>T: +45 75143022, E: post@jyskgeoteknik.dk | Denmark | X | | | X | | X | Drilling contractor for the oil industry. Soil surveys, environmental studies. |
| **ScanField Jordrens Køge ApS** https://scanfield.dk<br>Junckersvej 10,4600 Køge<br>T: +45 53 73 75 30, E: jord@scanfield.dk | | X | | | | | X | Soil and waste receiving and treatment facilities. |
| **Technical University of Denmark, DTU**, www.dtu.dk | DK, International | X | X | X | X | X | | |
| **University of Copenhagen**, https://www.ku.dk | DK, International | X | X | X | X | X | | |

# ANNEX 2: THE LIST OF THE MAIN NORMATIVE AND LEGAL DOCUMENTS REGULATING CONTAMINATED SOIL REMEDIATION ACTIVITIES IN RUSSIA

- Land Code of the Russian Federation
- Federal Law On Environmental Protection of 10.01.2002 No. 7- FZ
- RF Government Resolution On Cases of Organizing Work to Eliminate Accumulated Damage, Identify and Assess Objects of Accumulated Environmental Damage, as well as Amendments to Some Acts of the Government of the Russian Federation of 25.12.2019 No. 1834
- Environmental Protection State Programme of RF (approved by RF Government Resolution of 15.04.2014 No. 326)
- Regulations of Land Reclamation and Conservation approved by the RF Government Resolution On Land Reclamation and Conservation of 10.07.2018 No. 800
- GOST 33570-2015 Resources Saving. Waste Treatment. Identification Methodology. International Experience
- GOST R 57447-2017 Best Available Techniques. Reclamation of Lands Contaminated with Petroleum and Petroleum Products. Basic Principles
- GOST P 58486-2019 Nature Protection. Soils. Nomenclature of Sanitary Conditions Indices.
- GOST P 59060-2020 Nature protection. Lands. Classification of Disturbed Lands for the Purpose of Reclamation
- GOST P 59070-2020 Environmental Protection. Reclamation of Disturbed and Oil-Contaminated Lands. Terms and Definitions.
- GOST 17.4.2.01-81 Nature protection. Soils. Nomenclature of sanitary condition indices
- GOST 17.4.2.02-83 Nature protection. Soils. Nomenclature of suitability characteristics of disturbed rich soil layer to be backfilled
- GOST 17.4.3.02-85 Nature Protection. Soils. Requirement for Fertile Layer Conservation in Performing Earth-Moving
- GOST 17.5.1.01-83 Nature Protection. Land Reclamation. Terms and Definitions
- GOST 17.5.1.02-85 Nature Protection. Lands. Classification of Disturbed Lands to Be Recultivated
- GOST 17.5.1.03-86 Nature Protection. Lands. Classification of Overburden and Enclosing Rocks for
- Biological Recultivation of Lands
- GOST 17.5.3.04-83 Nature Protection. Lands. Reclamation General Requirements.
- GOST 17.5.3.05-84 Nature Protection. Land Reclamation. General Requirements for Lands to Be Backfilled
- GOST 17.5.3.06-85 Nature Protection. Lands. Requirements for Determination of the Fertile Soil Layer Standard Disposal while Performing Earth-Moving
- Code of Practice 11-102-97 Engineering Environmental Site Investigations for Construction
- Code of Practice 11-105-97 Engineering Geological Site Investigations For Construction
- Code of Practice 47.13330.2016 Engineering Survey for Construction. Basic Principles