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NATO/CCMS Pilot Study

Prevention and Remediation Issues in Selected Industrial Sectors: Rehabilitation of Old Landfills

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2004
Annual Report
NATO/CCMS Pilot Study

Prevention and Remediation Issues
in Selected Industrial Sectors:
Rehabilitation of Old Landfills

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NOTICE

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INTRODUCTION

The Council of the North Atlantic Treaty Organization (NATO) established the Committee on the Challenges of Modern Society (CCMS) in 1969. CCMS was charged with developing meaningful programs to share information among countries on environmental and societal issues that complement other international endeavors and to provide leadership in solving specific problems of the human environment. A fundamental precept of CCMS involves the transfer of technological and scientific solutions among nations with similar environmental challenges.

This document reports on the second meeting of the Pilot Study on Prevention and Remediation Issues in Selected Industrial Sectors. The purpose of the pilot study is to define and explore best practices for reducing the health and environmental impact on soil and groundwater from industrial sectors of interest (e.g., metals mining, organic chemical production, gasworks, and fertilizer manufacturing) as well as other unique site "types" (e.g., old landfills, privatization sites [i.e., facilities transitioning from former state ownership in certain categories], mega sites [i.e., large scale former industrial and mining facilities], and shoreline sediment sites). The pilot study will explore the techniques and technologies for preventing and avoiding discharge to soil and groundwater as well as measurement and remediation for that industry sector or site type. It seeks to engage industry and other private sector organizations at the transnational level in sharing and evaluating technical information. In reviewing case studies as well as experience from the previous CCMS pilot study on contaminated land and other sources, the proposed pilot study may be able to assess or benchmark "what is easy to clean," "what is difficult to clean," and "what is impossible, at reasonable cost, to clean." The unique contribution of the pilot study would be measured by its ability to synthesize information regarding best practices, successes and failures, and uncertainties for the sectors of interest.

The second meeting of the Pilot Study was held in Cardiff, Wales from May 23 – 26, 2004. This meeting dealt with the issues of rehabilitation of old (municipal) landfills. Nineteen technical papers fell under the broad topics of new remediation and monitoring technologies, strategies for completion and aftercare, and managing and treating landfill leachate and gases. The United States is the lead country for the Pilot Study, and nineteen other countries participated in the meeting. This report is a set of abstracts of the presentations at the meeting. In addition, a CD is available with copies of all the detailed presentations.

This report is available online at http://www.nato.int/ccms/ and http://www.clu-in.org/wales. CD ordering information can be found at the latter web site. General information on the NATO/CCMS Pilot Study may be obtained from the country representatives listed at the end of the report. Further information on the presentations in this document should be obtained from the identified presenters.

Walter W. Kovalick, Jr., Ph.D.
Director

ABSTRACTS INCLUDED IN NATO/CCMS PILOT STUDY

NEW TECHNOLOGIES AND TECHNICAL APPROACHES

OPERATIONG LANDFILLS AS BIOREACTORS TO DECOMPOSE AND STABILIZE SOLID WASTE

Timothy G. Townsend, Ph.D., P.E.
United States

1. ABSTRACT

Municipal solid waste landfills may pose environmental and human health risks as a result of contamination of underlying groundwater and emissions of landfill gas. These problems are most severe in sites where waste is or was disposed without control technologies such as leachate collection and gas extraction systems. Modern engineered facilities must still control potential migration of pollutants to the environment, and the current practice of limiting waste decomposition may simply be postponing future environmental problems.

A more sustainable approach to operating landfills that is gaining popularity is the operation of landfills as waste treatment units rather than simply as storage systems. Bioreactor landfills create conditions within the waste that promote rapid decomposition and stabilization through the addition of moisture and in some cases air. This approach has been applied to modern landfills to actively treat incoming solid waste, and to older sites where remediation of environmental risks is a prime objective.

This presentation provides an overview of the technologies involved with bioreactor landfills and presents a summary of the current state of practice of this technique in the US. Applications for both modern operation landfills as well as historical sites are discussed. A case study is described and data regarding leachate quality, gas production, and waste stabilization are presented.

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INNOVATIVE TECHNOLOGY FOR REMEDIATION OF LANDFILLS AND CONTAMINATED SOILS–INTERLAND

Thomas G. Reichenauer
Austria

1. ASTRACT

INTERLAND is an Austrian project that tries to bundle the national expertise in innovative remediation technologies on the scientific and the industrial side. The aim of the project is to test innovative remediation technologies in respect to applicability and provide a sound scientific basis for application of such methods. Technologies for old landfill sites as well as for contaminated soils (heavy metals and organic contaminants) are investigated. In project package 1 we investigate innovative landfill covers with respect to the water balance compared to conventional covers. In project package 2 we deal innovative methods for risk assessment of old landfills (FT-IR and bioassays) and oxygenation for degradation of the organic substances. In project package 4 we are performing pot and field experiments to investigate remediation of heavy metal contaminated soils by immobilization (by soil amendments) and phytoremediation. In project package 4 soils remediation methods for soils contaminated with organic compounds are investigated. The methods include biological (e.g. bioventing), chemical (e.g. oxidants) methods and phytoremediation of mixed contaminants.

The four project packages of INTERLAND are held together by the application of innovative monitoring methods like FT-IR for determination of organic substance in solid samples (waste and soil), the application of bio-assays (growth and reactivity tests) and the application of ^{3}H as a tracer for landfill leakage into the groundwater.

An overview over the ongoing project INTERLAND will be given with a focus on the activities in respect to landfill covers.

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FIELD WATER BALANCE OF LANDFILL FINAL COVERS

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United States

1. ABSTRACT

Landfill covers constitute a major expense to landfill operators, yet performance of specific cover designs has not been well documented and seldom compared in side-by-side testing. In 1998 the USEPA initiated a comprehensive study to evaluate conventional and alternative covers over a range of climates from humid to arid. At 11 field sites in seven states, from Georgia to California, we monitored conventional covers employing resistive barriers (soil layers with low saturated hydraulic conductivity or composite barriers consisting of a geomembrane over a soil barrier) as well as alternative covers relying on water-storage principles. Average percolation rates for the conventional covers with a composite barrier (geomembrane over compacted clay) typically were less than 1.4% of precipitation (12 mm/yr) at humid locations and 0.4% of precipitation (1.5 mm/yr) at sites in arid/semi-arid/sub-humid locations. Conventional covers with soil barriers (typically compacted clay) in humid climates had percolation rates ranging between 6-17% of precipitation (52 and 195 mm/yr). The high rates were attributed to flow through cracks and other defects in the soil barrier. Average percolation rates for alternative covers (monolithic designs and capillary barrier designs) ranged between 6 and18% of precipitation (33 and 160 mm/yr) in humid climates and generally less than 0.4% of precipitation (2.2 mm/yr) in arid/semi-arid/sub-humid climates. One-half (five) of the alternative covers in arid/semi-arid/sub-humid climates transmitted less than 0.1 mm of percolation. Two of the alternative covers have percolation rates much higher than anticipated due to inadequate storage or limited transpiration capacity. Comparisons were made between field-measured performance and simulated results using HYDRUS-2D and UNSAT-H and showed that modeled results deviated appreciably from field-measured data.

2. CONTACT

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Craig H. Benson, University of Wisconsin – Madison
Glendon W. Gee, Battelle Pacific Northwest Laboratories

NEW MONITORING APPROACHES

UNDERGROUND MONITORING SYSTEM

Paolo Costa, Antonio Campanile, Carlo Manna
Italy

1. ABSTRACT

The directional drilling method is widely employed for the placement of underground utilities. The rigs operate in many soil types including rock, cobble, and gravel.

The F.lli Esposito research group has developed specific technologies for soil recognition and path control in directional drilling. More specifically a proprietary wireline bore hole localization system for path control has been developed. This system captures the orientation and position of the bore hole assembly in real-time.

Another technology developed is a Real-Time Ground Recognition System for Horizontal Dry Directional Drilling. This is a learning system capable to recognize the underground features while drilling. In addition it's capable to store and enhance its experience with time. The real time underground recognition is based on data collected in a knowledge data base.

The research group has used these results for the development of a new machine applied to monitor underground pollution. This machine uses a tool similar to a needle for biopsy called geopsy needle since it achieves site diagnosis by aspiration through a needle as in tissue biopsy.

This machine extends the no dig technology to a new class of machine called no dig underground monitoring system (UMS).

UMS can be used for underground pollution monitoring and it extends pollution monitoring where present technologies cannot, for example where vertical core boring is not applicable for environmental constraints. The UMS is a directional drilling based system and therefore has the possibility to characterize the underlying zone of a site also when it is not accessible by other means.

UMS can be used in underground monitoring for: landfill pollution, industrial pollution, sewer leakage, oil leakage, toxic substances disposal, nuclear contaminated land and other applications.

Actually, two test applications are planned, in Italy, for system prototype: one at contaminat industrial site and another one in a polluted landfill area.

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OPTICAL REMOTE SENSING FOR EVALUATING AIR PATHWAYS AT BROWNFIELD SITES

Susan A. Thorneloe
United States

1. ABSTRACT

Fugitive air pollutant emissions from area sources such as industrial plants, agricultural operations, and waste facilities are becoming an increasingly important environmental issue. Due to the spatial extent and non-homogenous nature of these sources, quantification of the total pollutant emission using traditional point sampling and dispersion modeling techniques can be problematic. A method for rapid and direct measurement of pollutant emission flux from fugitive sources is highly desirable.

EPA's Atmospheric Pollution Prevention and Control Division (APPCD) is working to develop and standardize a ground-based optical remote sensing method to meet this important measurement need. The method employs open-path Fourier transform infrared and tunable diode laser spectroscopy to obtain path-integrated pollutant concentration information along multiple plane-configured optical paths. The multi-path pollutant concentration data along with wind speed and direction information are processed with a computational algorithm to yield a mass emission flux for the source. Control of systems and computations is highly automated allowing for generation of real-time flux emission information.

APPCD is partnering with the USDA, land-grant universities, and the agricultural industry to perform assessments of pollutant emissions from concentrated animal feeding operations. Through the Measurement and Monitoring Technologies for the 21st Century (21M2) initiative, EPA's Office of Solid Waste and Emergency Response is providing assistance to Region 8 and Region 1 in the evaluation of brownfield and superfund landfills being considered for recreational use or near-by development. APPCD is participating in a cooperative research and development agreement with Waste Management, Inc. to evaluate fugitive emissions from bioreactor landfills. Additionally, APPCD is working with the Department of Homeland Security in the adaptation of this novel optical remote sensing technology to their needs.

This measurement method is being used to determine emission factors for a variety of agricultural, mobile, and industrial fugitive sources. In particular, this technique plays a key role in emission characterization of brownfield landfills and also helps to evaluate new types of landfill operations including accelerated waste decomposition through aerobic, anaerobic, and hybrid type bioreactor landfills. Fugitive emission source data is provided to the Office of Air Quality Planning and Standards for emission inventories and to National Exposure Research Laboratory for atmospheric model input. Emission results are also provided to industrial partners as a technology evaluation diagnostic. This measurement method has additional applicability to the areas of remediation monitoring and emergency response.

The presentation for NATO will describe work that was recently conducted for 21M2 to provide data and information needed for determining suitability of recreational use or development of three brownfield landfills.

2. CONTACT

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STRATEGIES FOR COMPLETION AND AFTERCARE

STRATEGIES FOR MITIGATION OF ENVIRONMENTAL IMPACTS FROM A CLOSED MUNICIPAL LANDFILL

Steven Rose, Paul MacLatchy, Dale Van Stempvoort
Canada

1. ABSTRACT

The Belle Park landfill in Kingston, Ontario, is like many others that served this region during its lifespan from the early-1950s to the mid-1970s. It received mixed municipal wastes, and in its early years also received industrial wastes which were landfilled by direct placement on low-lying, swampy land adjacent to the City's then industrialized waterfront close to Lake Ontario. The Belle Park landfill is unique in that it occupies a triangular point of land approximately 44 hectares in area which extends into the middle of the Kingston Inner Harbour at the mouth of the Great Cataraqui River. Its configuration creates a water-edge boundary over more than 85 percent of the landfill perimeter which is approximately 3 kilometres in length.

Since the mid-1990s, the City of Kingston has been actively engaged in environmental characterization of this site and mitigative measures aimed at reducing the impact of landfill leachate on adjacent water bodies.

The site, now a multi-use recreational green space with a golf course built over the wastes, is directly influenced by Lake Ontario water levels. Annual fluctuations of Lake Ontario water levels causes up to thirty percent of the buried wastes to be flooded and dewatered on an annual basis creating unique challenges in managing leachate impacts from the site. To date, efforts to mitigate environmental impacts from this site have primarily consisted of repairing landfill cover where needed and operating groundwater extraction wells at locations of historically observed seepage.

Over the past two years, the City of Kingston has initiated two pilot feasibility studies to evaluate the potential for long-term passive remediation at this site. One study is reviewing the effectiveness of two native tree species Salix nigra (black willow) and Populus balsaminifera (balsam polar) to control shallow groundwater flow in the vicinity of controlled plantings of these tree species on the site. A second pilot feasibility study is investigating the effectiveness of a constructed wetland to remove contaminants of concern from diffuse leachate inputs into the adjacent river by establishing a fringe wetland constructed within the existing river. These pilot feasibility studies by the City are being supplemented by an independent study, conducted by Environment Canada, of several mature Salix nigra at the site. This study is examining the extent of influence that these mature trees have on the local phreatic surface.

Early data collected from these pilot feasibility studies provide a baseline for assessing changes in shallow groundwater flow and chemistry over the next three years. If these passive remediation technologies prove to be successful, they have the potential benefit of reducing overall remediation costs at the same time as integrating living natural systems into the environmental site management strategy.

2. CONTACT

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Paul MacLatchy
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3. SUPPORTORS

Malroz Engineering Inc.
City of Kingston
Environment Canada

STRATEGIES AND EXAMPLES OF LANDFILL CLOSURE

Gerhard Rettenberger
Germany

1. ABSTRACT

Due to German law it is the common method for landfill closure to finish the landfill with a two ceiling layers containing cover to still operate the gas and leaching collection system for a certain time and to monitor the landfill. This will be done within a period of 30 – 40 years. After that the landfill is given back to the land owner for further use.

As this procedure is quit expensive new regulations in Germany give the opportunity for alternative solutions depending from the kind and condition of the landfill. These alternatives can be divided into five topics:

- using other systems for cover ceilings can be chosen. These alternatives comprise different materials for the ceiling layers, different numbers of ceiling layers and different quality of ceiling materials;
- using special materials for the ceiling layers especially choosing waste materials as slags from incineration processes or sewage sludge;
- using methods for influencing the landfill body through water infiltration or aeration by pumping air into the landfill;
- using passive gas collection systems and treating of the gas with microbial methane oxidation processes either in technical filters or in the cover system; and
- using the upper layer of the cover especially for water evaporation by improving the water storage capability of the soil and the evaporation ability of the special chosen plants.

Especially the methods of the third topic give the opportunity to bring the landfill early in a stabilized condition so that in the future it has not be expected that degradation processes in the landfill will start again or continue. And the topic four gives the possibility to end with technical processes and turn to natural conditions.

The paper shows examples from landfills in Germany which has been closed by using the above described techniques.

2. CONTACT

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CLOSURE AND AFTERCARE REGIME FOR LANDFILLS BELOW THE WATER TABLE

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Germany

1. ABSTRACT

The closure and after care regime for landfills below the water table is discussed. The German landfill "Halle-Lochau" is a typical example of such a landfill in a former open cast mining. In the described research programme for the landfill "Halle-Lochau" a sustainable concept shall be developed to reach the aim to make secure that landfills in former open mining areas will meet ecological standards and economical restraints for any use after closure.

The landfill "Halle-Lochau" was created within a former open cast mining area without any liner or sealing at the base. As the landfill does not comply with current law and regulations, and as the landfill cannot be improved to the required standards using technical measures, the landfill has to be closed. However, the state of the art measures for closing landfills required by the authorities i.e. the construction of a top sealing system works only at those landfills which have their base above the groundwater level. But this situation does not exist at the landfill "Halle-Lochau" and at a lot of old landfills which are situated in former open cast mining areas.

One technical solution for such landfills could be controlling the groundwater level for an indeterminate period of time. This means the ground water level which was originally lowered down by using pumping systems to enable the mining and the subsequent landfill will be controlled below its natural position. In this case the landfill could be closed as demanded by the law. But this strategy does not fulfil the principles of environmental sustainability and minimal operational aftercare. Because the aim of any landfill technology is to cause no harm to human beings and the environment. At a certain stage after closure of the landfill once after care ceases.

Normally at a landfill where there is a groundwater pumping system installed to keep down the groundwater level after closure when the pumping stops the normal ground water table elevation will be re-established again and will flood the body at least partially.

In that case besides those measures which will have to be carried out in the phase of closure and aftercare additional measures have to be done to prevent either any contact of the groundwater and the landfill body or at least any pollution output of the landfill into the neighbourhood. In the described research programme for the landfill "Halle-Lochau," an example of a sustainable concept shall be developed. The concept shall include all regional and mining plannings with the aim to make sure that landfills in former open mining areas will meet ecological standards and economical restraints for any use after closure.

The results of the research work are of significant importance to the operator. Without finding a cost-effective feasible solution the landfill would have to be redeveloped by a complete restoration, which could be not financed in the described project, which is surely the same in similar cases.

Probably new technical solutions like in-situ stabilization or inertization may provide benefits for the project. If the present phase of the research works, it will show those benefits. It is intended to start firstly because of the huge size of the landfill with a test period to adapt and optimise the selected technique.

2. CONTACT

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WASTE, NOXIOUS SUBSTANCES MANAGEMENT LANDFILL CAP

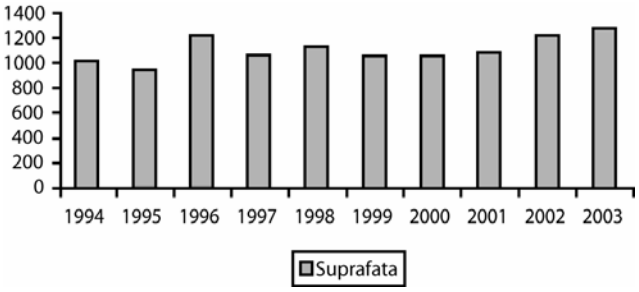
Tatiana Galitcaia
Moldovia

1. ABSTRACT

By the end of 2003 year ecological situation regarding management of solid wastes in Moldova still remained complicated. The major problems have been different stages of collection, processing, transportation and dumping of municipal wastes. This syndrome involves also the procedure of localization, compaction, and accumulation of waste in small-scales facilities thus representing a major source of soil and underground water pollution because no one knows the precise lifetime of such waste systems as for as liquid or volatile pollutants are concerned.

Additionally numerous landfills have lead to harmful effects on drinking water and human health hazards. For example, in many Moldovian settlement areas there are numerous landfill sites which can be described as environmental time – bombs. For domestic waste neutralization the Republic of Moldova has 43 dumps with total surface (in conformity with inventory work accomplished by Ecological Agencies) around 1304 ha. Total volume of domestic wastes compile roughly 25 ml. tons:

Surface Dynamic of Waste Dumping in Moldova Tons Per year



Non-authorized waste dumping 1077 sites covering in total on surface around 661,35 ha. compiling approximately 62 % from total existed dumping sites in Moldova.

Among toxic residuals with diverse compounds and origin the following should be listed:

- I class of toxicity – wastes containing cyanide – 6372,9 tons,
- II class of toxicity – wastes containing vanadium – 657,7 tons,
- containing petroleum products – 396,0 tons,
- III class of toxicity – oil products residuals – 320,1 tons,
- IV class of toxicity containing heavy metals (electro plating industry) – 1506,4 tons
- Etc.

Compiling around 12 000 tons.
The major disadvantages of landfill disposal include:

- The major potential risks for polluting water resources
- The potential risks of contaminating the soil
- The generation of landfill gas i.e. methane and carbon dioxide
- Potential human exposure to volatile chemicals
- Smell, vermin and fire
- Destruction of natural /virgin sites
- Long term and cost intensive clean- ups remediation and monitoring (aftercare , close –up)

Meanwhile landfill in our conditions has several advantages:

- It is not unduly capital intensive disposal method
- It is widely available
- It is comparatively insensitive to day – to day variations in the quantity and nature of the wastes deposited.
- It is appropriate in a wide range of circumstances (equipment, technology and skills are available virtually at the local levels).

As a result of serious environmental and health problems experienced with historic and abandoned dump sites and the very high costs associated with cleanup measures at contaminated sites, Moldova Government have introduced the specially engineered landfill concept.

Proper site selection, design of the landfill, control and management of operations, control on input wastes, installation of appropriate means for avoiding leachate outside the fill and reducing escape of landfill gas would be necessary to minimize the potential harmful effects of a land filling on public health and the environment and minimization of free liquids placed in the landfill as well as minimization of precipitation and run –on into the fills.

On that respect as on research Pilot Study can be considered Tintareni Landfill Cap, Chisinau, Republic of Moldova

Period of Operation – 1990 till present day, ***Location*** – Anenii Noi

History : At the end of 1998 – first decade of 1999 in the result of abundant rainfalls the accumulated moisture have activated landslides process that crushing 200m of protective dams heavily polluting adjacent soil and underground water resources. As a result by the municipality was launched on research remediation study and

Regulatory Requirements were established:

The following soil proprieties were used to evaluate performance: soil moisture, soil temperature, runoff and erosion, percolation and inter-flow, meteorology, and vegetation.

As a result landfill cover designs were established, a geosynthetic clay liner cover and 259 m drainage systems were provided. Around 55 thousands m3 of soil were removed and on reservoir 50 m3 for filtrate accumulation was built up.

For rain fall and surface water evacuation technical measures were provided,
For supervision and control of underground water quality on comprehensive monitoring system was established...

Sadly because lack of money all kind of preventive measures were not finished at the moment.

Costs: 2 mln 274 thousands Lei or roughly 200 000 USD.

As stated earlier, that landfill is used as a disposal option for selected hazardous wastes providing adequate safety measures including preventive selection and pre-treatment of wastes for minimization of hazard to the environment and human health protection. The minimization of precipitation and run – on into the fills is achieved. There are, however, a number of hazardous wastes for which mentioned landfill disposal is not appropriate and cannot be recommended for dumping:

- liquids and materials containing free liquids;
- highly volatile and flammable liquid wastes;
- wastes containing mineral oils;
- strongly oxidizing /reducing wastes;
- persistent organo-halogen compounds;
- clinical wastes;
- shock sensitive explosives ;
- compressed gases
- highly reactive wastes;
- volatile materials of significant toxicity;
- concentrated acids, alkalis; etc.

In fact for proper exploitation and engineering the amounts of waste that directly increase leachate volumes should be reduced to a practical minimum.

2. CONTACT

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ASSESSMENT AND RESTORATION OF THE BP LLANDARCY REFINERY LANDFILL SITE

Martin Chapple
United Kingdom

1. ABSTRACT

The Llandarcy refinery was commissioned in the 1920s and at its peak in the 1970s ands early 1980s was the largest operating UK refinery. However following rationalisations in the late 1980s and early 1990s, closure was announced in 1997. The site occupies approximately 250 ha and is situated on a complex geological sequence adjacent to and upgradient from Wales' largest Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC). The site is now being considered for an ambitious programme of redevelopment as mixed light industrial and residential use.

One of the major issues at the site is the refinery landfill site. The landfill was constructed on land reclaimed from the Crymlyn Bog immediately prior to WW2. While some putrescible waste was disposed, the majority of the material disposed consisted of a variety of other refinery solid wastes including demolition rubble, pyrophoric waste, asbestos, vanadium-rich refractory waste, and fuller's earth. Significantly, the area used for the landfill was part of a wider area used as a containment area for oily discharges. Unlike many landfills, the principal issue is not gas or leachate, but free oil, which is migrating towards the SSSI.

The methodology for the investigation and assessment process were agreed between BP, the Environment Agency, the Countryside Council for Wales, and Local Authority in advance of the works. Investigations were completed in 1999 and a Quantitative Risk Assessment (QRA) was undertaken to identify potential risks to the SSSI from the landfill. The QRA provided BP and the Environment Agency with the most cost-effective way to identify and manage the problems at the facility. After Agency review of the QRA, a Remedial Action Plan (RAP) was developed and approved with them, which outlined a long-term strategy to mitigate the potential risks to offsite receptors and address mobile contaminants within the landfill, supported by a monitoring plan, leading ultimately to the future return of the licence. This plan is currently being implemented by BP.

2. CONTACT

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CLOSURE OF THE BRITANNIA SANITARY LANDFILL SITE – IS IT THE END OR JUST THE BEGINNING?

Larry Conrad
Canada

1. ABSTRACT

The presentation by the Region of Peel's Waste Management Division will show how a closed landfill is being converted to a championship golf course and green power generation facility. The Britannia Sanitary Landfill Site reached its approved capacity and closed in June 2002 after serving the Region of Peel for more than 20 years. Although closed there is still work to be done to ensure that the community is protected from any adverse impacts associated with the closed landfill site.

In 1997 the Region with its partner the City of Mississauga opened an 18 hole golf course on a closed portion of the site. The Britannia Hills Golf Course is operated by the City of Mississauga; the City where the landfill is located. With the full closure of the landfill site in June 2002, the Region and the City are expanding the existing golf course to include an 18 hole championship course, a 9 hole executive course, a driving range, and a large clubhouse with banquet facilities. The Region has also formed a partnership with a private landfill gas operator to collect methane gas from the site and use the gas to generate green power (electricity). The green power will then be sold to the Region's Lakeview Wastewater Treatment Plant to displace conventional power. The presentation will outline the planning and approvals process and well as the engineering details that went into the redevelopment of the site.

2. SPECIFICALLY, WHY IS THIS TOPIC OF INTEREST TO 2004 NATO/CCMS DELEGATES?

This will be of interest to the members for two major reasons. The first is because the landfill site served the Region for over twenty years. Through out the active life of the site the end use was planed to be a golf course. This session will highlight how the golf course was planned, developed and delivered including the relationship that was developed with the partner municipality, the City of Mississauga. The second stems from the incredible amount of emphasis that the Region of Peel has placed on the clean air initiatives within the Region. The session will also explain the process that it followed to ensure that the landfill gas produced at the site is dealt with and how it became a supplier of power to its own waste water treatment plant.

3. LEARNING OBJECTIVES

- How to develop win-win situations with environmentally unfavorable sites.
- Leading edges in Public Partnerships and how to make them work.
- How to develop initiative financing solutions for environmentally friendly projects.

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MANAGING AND TREATING LEACHATE

DILUTE AND DISPERSE LANDFILLS: EVIDENCE FOR NATURAL ATTENUATION

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United Kingdom

1. ABSTRACT

In the 1970s the UK government initiated a programme of research into the effects of waste disposal on soil and groundwater. The core research programme involved the investigation of twenty landfill sites (representative of the main geological settings in the UK and categories of waste permitted) and was published in 1978 in the "Brown Book". (Sumner, 1978). The main findings included that:

- pollution plumes around landfill sites are often restricted in extent;
- the site geology and hydrogeology, especially the presence of an unsaturated zone, are of great significance in determining the degree of attenuation of leachates; and
- attenuation mechanisms (defined broadly to include dilution) are available in the landfill and underlying strata.

Following the "Brown Book" a number of landfills have been subject to investigation to gain a better understanding of landfill processes and attenuation mechanisms. The Thriplow landfill, Cambridgeshire was chosen for detailed study and evaluation of the fate and transport of landfill leachate in the Chalk aquifer. It forms two discrete pits, occupying sand and gravel workings above the Middle Chalk, that were filled with household, commercial and industrial wastes in 1957-1977 and 1981-1987. This study has involved several phases of non-invasive and invasive site investigation to collect data and reduce the uncertainty in the hydrogeological conceptual model.

A range of traditional and innovative investigative techniques were employed to address specific uncertainties in the conceptual model, in particular concerning:

- waste characterisation and leachate distribution;
- hydrogeology of aquifer and groundwater flow;
- leachate release mechanism; and
- natural attenuation processes.

The techniques employed and the results obtained are discussed in relation to the uncertainty in the conceptual model at different stages of the investigation. The findings from this study are discussed in the context of the management of risks to groundwater from old landfill sites and in particular demonstrate the level of investigation needed to adequately define the landfill source term and provide evidence to assess whether natural attenuation is occurring.

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MULTIFUNCTIONAL PERMEABLE BARRIERS CARRYING WELL-PERFORMING MICROBIAL BIOFILMS FOR TREATMENT OF MIXED POLLUTANT PLUMES

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1. ABSTRACT

In order to remediate contaminated groundwater, many techniques have been developed and applied. However, although groundwater is often polluted with complex mixtures of different chemicals, most remediation techniques only deal with one or a few pollutant types. Sanitation of groundwater polluted with mixtures of hazardous compounds has received wrongly less attention and remains a problem. A combination of different existing technologies may be a solution, but one should consider (I) the impact of one remediation technique on another one and (II) the influence of co-contaminants on the removal efficiency of the processes.

In 2001 the EU-project MULTIBARRIER was started with 8 European partners (Vito-Belgium, LFU-Austria, UW-The Netherlands, TUM-Germany, IBA-Germany, Biotecs- Germany, UP-Czech Republic, DEC-Belgium). The study focuses on MULTIBARRIERs, i.e. permeable reactive barriers in which different pollutant removal processes (biological and physicochemical processes) are combined to treat in situ groundwater containing mixed pollutants. Different MULTIBARRIER concepts to treat groundwater were designed, evaluated and compared. One of the objectives of the study was to answer the question whether the removal processes should be applied one after the other (sequential MULTIBARRIER), or whether a combination of different processes in one zone (mixed MULTIBARRIER) is also possible. The latter may require more optimization but the installation is expected to be less complex and less expensive. Another important question concerns the choice of the terminal electron acceptors (TEA) for the biological process.

In a first stage of this work, lab-scale batch and column tests were set-up to evaluate several sequential and mixed MULTIBARRIERS. A model pollutant mixture was defined consisting of (i) the heavy metals zinc (5 mg/l) and arsenate (0.2 mg/l), (ii) the chlorinated ethenes PCE (2 mg/l) and TCE (5 mg/l), and (iii) the aromatic hydrocarbons benzene, toluene and m-xylene (BTX, 2 mg/l each). The investigated pollutant removal processes were reductive dehalogenation of the chlorinated aromatic hydrocarbons (CAHs) with zero valent iron, sorption/reduction of the metals and biodegradation of BTmX and also some CAHs. In the biobarrier oxygen, nitrate, sulfate as well as iron were tested as terminal electron acceptor (TEA). As oxygen and nitrate are known to have a negative influence on the performance of zero valent iron, only sequential MULTIBARRIERS (Fe0 + BIO) were tested with these TEAs. In all concepts, the sorption part was considered mainly as a polishing step. In one column set-up the Fe(III) generated during corrosion of the zero valent iron was present as only TEA. Both mixed and sequential MULTIBARRIER configuration showed to be suitable for sanitation of mixed groundwater pollution. Indications were found for an improved removal in mixed systems. In all tested MULTIBARRIER concepts chlorinated ethenes and heavy metal removal was observed when zero valent iron was present, except in the columns where Fe(III)EDTA was added as TEA. Biodegradation of BTmX was observed under aerobic, denitrifying and iron reducing conditions, but to a much lesser extend when sulfate was present as TEA.

In a second stage of this work, a partially mixed MULTIBARRIER was installed on pilot scale in a container system (5m x 2.4 m x 2.4 m) in which an aquifer is simulated. The tested MULTIBARRIER consists of a mixed Fe0+BIO zone followed by an anaerobic BIO-zone and a sorption zone. Iron (III) originating from the corrosion of the zero valent iron was selected as TEA. Besides monitoring of the chemical composition of the groundwater and the field parameters, in situ mesocosm socks and molecular techniques like PCR-DGGE are being used to monitor changes in the microbial population in the different zone.

In the future MULTIBARRIER concepts for treating complex mixed pollutions, such as groundwater polluted with leachate, will be developed and tested.

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THE USE OF CONSTRUCTED WETLAND IN THE TREATEMENT OF LANDFILL LEACHATES

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1. ABSTRACT

Landfills produce leachates (water polluted by waste) that must be treated within the context of these sites remediation work.

We know from experience that, for some types of landfills, it is technically and economically more profitable to treat the leachates with natural attenuation rather than with usually known methods (mechanical, electromechanical, physico-chemical methods).

Actually, through numerous environmental diagnoses on landfills, we observed the functioning of treatment mechanisms in their natural state leading to high treatment efficiency.

From this observation, in 2002-2003 we carried out with the financial aid from ADEME, a work of development and research to point out typical solutions for landfills remediation whose environment proves a propensity for natural attenuation of pollutants.

The study was composed of:

A typological statistical analysis concerning 1 400 landfill sites with the identification of the 2 types being adapted to the treatment by natural attenuation; a bibliographical analysis over the unitary mechanisms that contribute towards attenuation; and the creation of 2 treatment systems being adapted to the 2 types of landfills.

The study shows that the use of constructed wetlands, added to other solutions of that kind (for example stabilisation ponds) proves to be a treatment solution that is appropriated to the 2 identified types of landfills.

Furthermore, the study points out that 15 to 20 % of old sites reveal a problem of leachates residual production after closure. It also shows the importance of using both surface and sub-surface mechanisms (change of treatment types with or without oxygen); thus, we can expect a good removal and efficiency with:

wetlands with surface flow:
wetlands with sub-surface flow:

Thus the study explains the various mechanisms taking place within wetlands and details the technical improvements that can be considered in the particular case of landfills.

Lastly, besides the obvious interest of treatment, the techniques using the mechanisms of natural attenuation afford a major economic interest. Investment costs are thus 3 to 5 times less high than those of a usual treatment. Operation costs are 5 to 9 less important than those of a usual treatment.

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MANAGING LANDFILL GASES

IDENTIFICATION OF METHANE HAZARDS NEAR MUNICIPAL LANDFILLS-TWO AUSTRALIAN CASE STUDIES

Manuel Fernandez
Australia

1. ASTRACT

With the ever-expanding urban sprawl in Sydney, New South Wales (within Australia's most populated state), lands that were once considered to be on the fringes of urban areas are now being sought after as prime residential land. This demand for urban land which has been on the rise, particularly in the last 10 to 15 years, has made some of the residents of these new fringe developments neighbours with old municipal landfills. Identifying and characterising potential methane hazards near the neighbouring residential subdivisions is important in the landfill rehabilitation process.

Two Australian case studies are presented which illustrate investigation and monitoring techniques used to identify possible methane hazards near residential subdivisions which were built in close proximity to old municipal landfills and had interesting results.

Case Study 1 shows how site history combined with a geophysical survey (electromagnetic profiling) and targeted gas well installations was used to identify the presence of methane near the boundary between the landfill and a new residential subdivision. The assessment process was successful in identifying a segment of the landfill boundary where landfill wastes and methane were encountered within the rear of the residential properties.

Case Study 2 presents an interesting finding from a methane investigation carried out near another residential subdivision located on the boundary of an old municipal landfill, where elevated methane concentrations were found in the soils within the subdivision. Extensive field and laboratory investigations were carried out to characterise the potential sources and migration pathways for the methane. The results of the study suggested that the methane found in the residential subdivision was actually being generated from organic material in the fill and natural soils on the subdivision and was unlikely to be derived from the municipal landfill.

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PHYTOTOXIC DAMAGE AND REMEDIAL ACTIONS AT AN OLD LANDFILL SITE IN SOUTHERN ITALY

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1. ABSTRACT

Over 2,000,000 m^3 of municipal solid wastes have been disposed in Paenzano landfills, sited in the city of Tufino near Naples, Campania, southern Italy, in the periods 1996÷1999 (Paenzano 1 landfill) and 1999÷2001 (Paenzano 2 landfill).

The site study, performed by SOGIN for the Government Commissioner for Waste Emergency in the Campania Region, through indirect investigation methods has proved the efficient bottom sealing of both landfills, confirmed by the absence of leachate contaminants in groundwater (placed 100 metres below ground level and 50-60 metres from landfills bottom). However site characterization has proved that landfill gas has spread in the surrounding grounds near the two landfills. Landfill gas shows high temperatures near the top soil (soil depth: 1m) with a significant thermal field recorded up to 500 meters distance from landfills centre.

A phytopatological investigation was carried on the decline condition of several fruit trees (i.e. Hazel tree, Walnut, Apricot, ect.) grown within or around the landfill area. The main cause of the decline was identified with the biogas escaped from the limits of the landfill. The temperature of these gas rises approximately 40°C at the depth of one meter and causes the death of root phloem, while the methane penetrated in the soil-texture induces a heavy anoxia.

A mitigation plan based on two typologies of gas extraction well networks has then been laid out: wells for the extraction of the landfill gas inside the landfills connected to a plant of recovery and production of electric energy, perimetrical wells beyond landfill boundaries having a barrier function to landfill gas diffusion outside landfill bodies.

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OTHER

STUDY OF A PCB-CONTAMINATED SITE AND EVALUATION OF REHABILITATION METHODOLOGY (BY THE EXAMPLE OF THE CITY OF SERPUKHOV)

Sergey Tikhonova
Russia

1. ABSTRACT

PCBs are highly toxic and persistent substances. It is estimated that approximately 30,000 tons of PCB-containing liquids still remain in equipment and storage containers throughout the Russian Federation. This inventory represents more than 90% of the PCBs that should be collected and destroyed. Currently, hazardous waste landfills are extremely scarce and existing sites are overfilled. Commercial PCB destruction facilities are non-existent. There are only three-four industrial facilities in Russia that process PCB-containing waste from their own transformers.

Current storage conditions are inadequate and there are many cases where leakage and spillage into the environment is possible. This situation is getting worse every year and urgent measures are required. The problem of remediation of PCB-contaminated sites and evaluation of rehabilitation methodology includes the following tasks:

- definition of the criteria for identification and characterization of the most hazardous PCB-contaminated areas to define the priority of rehabilitation;
- consideration of the best world practice of PCB-polluted soils rehabilitation verified in large-scale projects; and
- selection of environmentally sound measures or technologies both for restriction of human exposure, and for rehabilitation of PCB-contaminated areas.

For rehabilitation of the specified territory (the estimated total amount of PCB in soil at Serpukhov region is ca. 340 tons) eleven foreign and five Russian both "on site" and "off-site" remediation technologies were considered.

The existing international and Russian soil remediation technologies were categorized on the basis of the treatment place into "on site" treatment and remediation with soil removal and its sequential treatment ("off-site").

All the considered foreign technologies of soil treatment both "on site" and "off-site" have passed industrial tests and ensure the residual PCB content which in compliance with the environment requirements.

Among the known Russian technologies of PCB-containing soil treatment both "on site" and "off-site" the bioremediation technology and the cyclone kiln technology are the most interesting ones. Bioremediation has been tested in industrial scale and cyclone kiln technology has passed both pilot and industrial scale tests. For complete treatment of the PCB-polluted soil by bioremediation, this technology should be applied during five years.

Environmental, technological, economic, and administrative criteria for remediation of PCB-contaminated soil were determined for estimation of various technologies. These may be guidance for both environment and local authorities.

Remediation measures were considered as follows: short-term actions designed for quick response in connection with a direct threat to human health and the environment, and long-term actions, which should be carried out in order to minimize long-term PCB distribution and impacts.

On the basis of the existing Russian technologies and gained data on the Serpukhov district the following methods were proposed:

- remediation of soil in the waste water treatment system's core pools of the plant "Kondensator" with the area of about 3 ha using cyclone kiln technology or technology of thermal desorption;
- remediation of soil in the district "Zaborie" with the area of 200 ha using physico-chemical treatment with humino-mineral concentrate and bioremediation;
- administrative and organizational actions aimed towards minimization of production and consumption of agricultural products to reduce human exposure.

The track record of these Russian soil remediation technologies is short yet, but they may be applied in the Serpukhov area. However, additional information may be required before their application, i.e. concerning the fate of humic acid bound PCB during the soil remediation using humino-mineral concentrate (HMC).

The results of the carried out work are as follows:

The general criteria for hazard characterization have been considered with revealing of pollution sources, criteria were suggested for identification of PCB-polluted territories, major of which are the increased death rate, sickness rate and PCB content in breast milk. The increased values of these criteria revealed at the Serpukhov's territory have initiated sanitation survey, which showed the site pollution with chlorinated biphenyls used for a long time by the plant "Kondensator" for capacitor production. Consideration of the suggested technologies using mentioned above criteria has shown that the isolation technology was the only acceptable one for application at small territories. Bioremediation may be used, mainly, for treatment of the large territories, including that of agricultural croplands. The technology of liquid-phase vitrification is of the best fit for remediation of small territories with PCB content more than 50 mg/kg and their deep penetration into soil.

For "off-site" rehabilitation of PCB-polluted territories, the technologies of thermal desorption, the technologies using rotary kilns, mobile installation with the "oxy-fuel" torches, and that using the cyclone kiln may be preliminary recommended.

The order of the actions preceeding to realization of PCB-containing soil remediation was considered. It was shown that the order of these actions should be: preliminary study of the polluted territory, full inspection, delivery of the input data for carrying out of the feasibility study and design works, execution of the business-plan.

Remediation measures were classified to the following categories: short-term actions designed for quick response in connection with a direct threat to human health and the environment, and long-term actions, which should be carried out in order to minimize PCB distribution and impacts.

The evaluation of efficiency of risk reduction measures was executed by using the method "expenses estimation – effect". Here, following remediation options were considered: remediation of the former core pools of the plant "Kondensator" with the area of about 3 ha using cyclone kiln and thermal desorption technologies; remediation of agricultural area in the district "Zaborie" with the area of about 200 ha by using the bioremediation technology and the alternative action on reduction of exposure by administrative and organizational actions which aim towards shrinkage of production and consumption of PCB-contaminated agricultural products.

On the basis of the results of expenses efficiency analysis, it was recommended to treat the core pools of the plant "Kondensator" by using cyclone reactor or thermal desorption technologies, as these allow to remediate soil up to the depth of 0.5 m. Bioremediation was recommended for soil remediation in the district "Zaborie". Administrative and organizational actions were recommended as auxiliary, additional ones, which will allow reduction of the human exposure.

For remediation of the core ponds with the area of 3 ha, rather simple and inexpensive thermal desorption method may be used. Before preparation of specific action plans for remediation of 200 ha area it is necessary to evaluate opportunities of application of several remediation techniques, since use of a single technology for such a large area may be not feasible.

For phase-out of polychlorinated biphenyls in the Russian Federation it is necessary to develop, ratify and implement a program, for example "National Strategy and Action Plan", financed by the Russian sources under support of the international financial organizations. The program should include identification and prioritization of other PCB polluted territories remediation.

The following certain measures are to be carried out: acquisition of the authentic and duly statistical information concerning the dynamics of death rate caused by oncological diseases and monitoring of PCB content in breath milk; characterization of the polluted territories with identification of pollution sources; risk estimation for the identified territories; carrying out of subsequent monitoring of such territories; establishment of an All-Russia Register for these territories; drawing up of a list of environmentally sound remediation technologies.

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LANDFILL ASSESSMENT, REMEDIATION AND MONITORING AT REMOTE ARCTIC AND NORTHERN CANADIAN CONTAMINATED SITES

Joanna Ankersmidt, Michael Nahir, Wayne Ingham
Canada

1. ABSTRACT

Indian and Northern Affairs Canada (INAC), through its Northern Affairs Program (NAP), is responsible for 825 sites of concern that require action as part of the Contaminated Sites Program (CSP). These sites are all located in Northern Canada and in many cases in an Arctic and permafrost environment. Of the total number of sites, 328 have been assessed and 497 remain to be assessed. The sites have been classified as known or suspected chemical contaminated sites, or physical hazard sites.

Using the Canadian Council of Ministers of the Environment (CCME) National Classification System (NCS), 63 of these sites have been classified; of those, 42 have been ranked as Class 1 sites, where action is required. The majority of the Class 1 sites are abandoned Distant Early Warning (DEW) Line intermediate sites or related radar and communication sites that have been the responsibility of INAC since their closure and abandonment starting in the early 1960s. The remaining sites are primarily abandoned mine sites.

INAC has completed the assessment and remediation of a number of contaminated sites. Included in the work performed to date has been the assessment and remediation of the landfills associated with communication sites that are the responsibility of the Federal Government. INAC is currently in the process of developing a consistent assessment and remedial approach plan for application to all of the contaminated and mine sites for which they are responsible. The work performed to date as well as the approaches adopted by other agencies are reviewed and adapted to suite the current program requirements. Specific attention is given to the technical requirements and restrictions imposed through logistical challenges and advantages of working in a remote arctic environment while ensuring effective remediation within the applicable regulatory framework. Landfill assessment, remediation and post construction monitoring aspects of the program will be addressed.

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PILOT STUDY MISSION

NATO/CCMS Pilot Study: Prevention and Remediation Issues in Selected Industrial Sectors

1. BACKGROUND TO PROPOSED STUDY

The current NATO Pilot Study on technologies for cleanup of contaminated land was completed in 2002. The pilot study was concluded for several reasons. The primary reason is that general information on technologies, processes, and methodologies for the cleanup of contaminated land and groundwater has been discussed and distributed by the pilot study in its meetings and annual reports. Thus, the goal of the pilot study has been accomplished. There is ongoing interest by participating countries and countries with developing contaminated land programs to continue a dialogue, to focus on specific industrial sectors, and to maintain technical contacts and information flow provided by the current "network" of pilot study participants. Thus, a new pilot study is proposed to allow this long-standing global network on contaminated land to continue.

2. PURPOSE AND OBJECTIVES: NEW PILOT STUDY - SECTORAL APPROACH

Much of the work of the past pilot study on contaminated land has drawn on case studies of technologies applied to a wide variety of industrial and land contamination settings. While useful for explaining the basis for the technology, its costs, and applicability, the information available is not focused on certain problems or site types at a variety of scales, contaminant concentrations, geological conditions, etc. Thus, the current pilot study is a "technologist's" view of characterization and remediation approaches.

Of more relevance to governments, industry, and the remediation services industry is interpretive information about the measurement and clean up of certain contaminants in specific industrial sectors in a variety of hydrogeological settings and levels of severity of risk. In addition, environmental protection has embraced more holistic concepts of preventing problems as a first priority. Thus, methods for preventing pollution (both by process changes and by land use and planning initiatives) coupled with remediation efforts are a priority for new and existing industrial development and for newly industrializing countries. This "integrated" approach can positively affect land and groundwater contamination as well.

Thus, a new CCMS Pilot Study entitled **Prevention and Remediation Issues in Selected Industrial Sectors** is proposed. The purpose of the proposed pilot study would be to define and explore best practices for reducing the health and environmental impact on soil and groundwater from industrial sectors of interest (e.g., metals mining, organic chemical production, gasworks, and fertilizer manufacturing) as well as other unique site "types" (e.g., old landfills, privatization sites [i.e., facilities transitioning from former state ownership in certain categories], mega sites [i.e., large-scale former industrial and mining facilities], and shoreline sediment sites). In reviewing case studies as well as experience from the current pilot study on contaminated land and other sources, the proposed pilot study may be able to assess or benchmark "what is easy to clean," "what is difficult to clean," and "what is impossible, at reasonable cost, to clean."

3. SCOPE OF WORK

The duration of the proposed pilot study is three (3) years. The study would commence by selecting industrial sectors. The pilot study meetings would be devoted to the techniques and technologies for preventing and avoiding discharge to soil and groundwater as well as measurement and remediation for that industry sector or site type. Countries would nominate expert speakers on such topics as industrial operations; problem definition and risk assessment; measurement and monitoring strategies; and remediation approaches for both soil and ground water. These speakers could represent many stakeholders - including industry, government, technologists, and consultants. The pilot study would seek to engage industry and other private sector organizations at the transnational level in sharing and

evaluating technical information. The unique contribution of the pilot study would be measured by its ability to synthesize information regarding best practices, successes and failures, and uncertainties for the sectors of interest.

A typical pilot study meeting would explore topics such as:

- Industry overview and assessment including typical waste stream and contamination issues
- Risk assessment methodologies
- Preparedness and planning issues
- Site characterization and monitoring approaches
- Prevention and remediation strategies including technologies and methodologies
- Institutional, financial, and public participation aspects of prevention and remediation

In addition, countries would be given the opportunity to present a general update of prevention and remediation activities via a *Tour de Table* as well as to provide country-specific industrial sector information. A limited number of countries would be selected to provide these detailed updates at each meeting.

It is proposed that the industrial sector of interest would be matched to the special interests to the potential host country for the meeting. Thus, host countries would have primary responsibility for involving industrial sector representatives and, possibly, developing a field visit to the affected sector.

4. ESTIMATED DURATION

Pilot Study Meetings:	September 2003 - September 2005
Completion of Final Report:	Spring 2006

5. PRODUCTS

An industrial sector report will be developed after each meeting. These reports will include invited papers from the industrial sector assessments as well as summary information on the monitoring and evaluation of risks and strategies for prevention and remediation. Country update reports will also be included.

6. NON-NATO PARTICIPATION: BALKANS, CENTRAL ASIA AND OTHER DEVELOPING COUNTRIES

In 2001, NATO/CCMS identified key objectives that would assist developing countries. These objectives include:

1. Reducing the impact of military activities

2. Conducting regional studies including cross-border activities

3. Preventing conflicts in relation to scarcity of resources

4. Addressing emerging risks to the environment and society that could cause economic, cultural and political instability

5. Addressing non-traditional threats to security

The proposed pilot study, *Prevention and Remediation Issues in Selected Industrial Sectors*, specifically addresses #4 and also covers aspects of #'s 1, 3, and 5. The proposed pilot study would target specific industrial sectors based upon interests of countries with newly industrializing and developing economies. The study would provide these countries with a base of technical information and with a network of

experts from whom to obtain advice. This proposal offers the opportunity for current pilot countries to continue networking and information sharing, and also provides a focus for discussions driven by partner country needs.

7. REQUEST FOR PILOT STUDY ESTABLISHMENT

It is requested of the Committee on the Challenges of Modern Society that it approve the establishment of the *Prevention and Remediation Issues in Selected Industrial Sectors Pilot Study*.

Pilot Country:	United States
Lead Organization:	U.S. Environmental Protection Agency