Remediation of Contaminated Sites in Canada

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ABSTRACT

Hundreds of contaminated sites have been generated due to the past mismagement of toxic substances, the lack of adequate environmental controls and ignorance of the potential environmental impacts of general activities in Canada. The general public, industry and governments have been addressing the contaminated sites with a number of cleanup responses. Environmental protection and remediation have become top priorities for the public and private sectors alike in Canada.

Between the late 1980s and the early 1990s, the Canadian Environmental Protection Act and Canada's Green Plan were followed by provincial and territorial laws and policies to regulate contaminated sites. The National Contaminated Site Remediation Program(NCSRP) was initiated in 1989. It has been administered through bilateral agreements between the federal and participating provincial/territorial governments. They have committed a total of $250 million toward orphan site cleanup and technology development/demonstration over a five year period. The federal government has committed an additional $25 million to assess contaminated sites on federal crown land.

Over 40 orphan high-risk contaminated sites, over 230 federal sites and over 35 technology development/demonstration projects have been addressed. The Canadian Council of Ministers of the Environment has developed a series of guidance documents to ensure a consistent and successful implementation of the Program.

The management/regulation scheme of contaminated sites generally consists of: 1) identifying and investigating sites, 2) determining site contamination, 3) recognizing responsibility and liability, 4) assessing priority for remediation, 5) activation, evaluation and implementing remediation options, and 6) documenting remediation completion.

The NCSRP supported the successful development/demonstration of a wide range of innovative remedial technologies. They are related to stabilization/solidification, thermal extraction, chemical fixation, enhanced bioremediation. soil vapor extraction, air sparging, soil washing/flushing, advanced oxidation, sonics, electrokinetics and other processes. They were applied mostly to remediate soils, sediments, and groundwater contaminated with hydrocarbons, PAHS, PCBs, heavy metals, and other hazardous pollutants in a variety of site environments.

Introduction

Canadians are discovering that the past mismanagement of toxic substances, the lack of adequate environmental controls and ignorance of the potential environmental impacts of their activities have generated hundreds of contaminated sites across Canada. Site contamination originated principally from soil contamination due to the placement of hazardous materials on or in the ground.

Different types of contaminated sites include soil and ground water contaminated by leaks from underground storage tanks, areas where industrial or transportation spills were not properly cleaned up, remnants of improperly decommissioned industrial facilities, and hazardous waste landfills. Governments and industry have been addressing the contaminated sites issue with a number of cleanup responses. In recent years, environmental protection and remediation have become top priorities for the public and private sectors in Canada..

Canadian Directions for the Environmental Protection of Soils

Environment Canada is the federal department of the environment. It was established subsequent to passage of the Government Organization Act of 1970(Hasan 1996). It includes the federal Environmental Protection Service unit responsible for the enforcement of environmental legislation on federally-owned lands, in interprovincial governments to enact appropriate legislation to manage the various environmental qualities in Canada. Canadian provinces have their own laws to control wastes.

However, in 1988, The comprehensive Canadian Environmental Protection Act came into force as the flagship of federal environmental laws and the first major federal statute over a decade. As a single piece of legislation, it consolidated the following existing environmental statues: the Environmental Contaminants Act, the Canadian Water Act, The Clean Air, Act, and the Ocean Dumping Control Act. It, also, has the purpose of ensuring uniform national standards for the management of toxic substances. Using the cradle-to-grave concept, it fomulates the regulations to control the entire life cycle of toxic substances from the initial import by a manufacturer through its handling and use, to the final disposal or release into the environment.

Contaminated sites result largely from soil contamination due to the placement of toxic substances into or on the land. Contaminated soils, in turn, impact other environmental matrices, i.e., water, air, and biota of the sites. Naturally, the environmental protection of soils becomes the central objective of any contaminated sites remediation program. Between the late 1980s and the early 1990s, the federal, provincial, territorial and municipal jurisdictions of Canada developed important laws and policies for regulating contaminated sites. They include Canada's Green Plan, British Columbia's Bill 26-1993 Waste Management Amendment Act, Alberta's Environmental Protection and Enhancement Act, Ontario's Environmental Protection Act, and Quebec's Contaminated Site Rehabilitation Policy(BCE 1991, 1993-1:GC 1990).

National Contaminated Site Remediation Program

The magnitude of the problem and the need for a consistent national approach to deal with the contaminate sites issue were recognized. Thus, this issue was placed on the agenda of the joint federal provincial-territorial Canadian Council of Ministers of the Environment(CCME) in 1989. Subsequently, the National Contaminated Sites Remediation Program(NCSRP) was established in that year.

The NCSRP has the following primary objectives: 1) to identify high risk contaminated sites that threaten human health or environmental quality and carry out remedial action through the effective application of the "polluter pays principle", 2) to provide the necessary resources to deal with "orphan" high risk sites, i.e., those sites for which the owner or responsible party cannot be identified, or is financially unable or unwilling to carry out the necessary work, 3) to work with private industry to stimulate the development and demonstration of new and innovative site remediation technologies in Canada(CCME 1994-1; EC 1996; Tilden 1994).

The NCSRP has been delivered prinicipally through bilateral agreements between Environment Canada and the individual provincial or territorial environment departments. The bilateral agreements set forth guiding principles, eligibility criteria, administrative procedures for governing activities and expenditures, and identifying the respective roles and responsibilities of the participants. The Government of Canada and the individual provinces and territories have committed a $250 million budget over five years from 1990. Funding has been provided on a 50/50 cost-shared basis. The Government of Canada's share of $125 million has been matching provincial-territorial funding on a basis proportionate to the population of the respective provinces or territories. More than 40 orphan sites vary widely. However, the majority are hydrocarbons and heavy metals. Other contaminants found include industrial/hazardous wastes, metals, PCBs, and wood treatment chemicals.

NCSRP-CCME Guidance Documents

CCME has been developing a series of documents to ensure the consistent and successful implementation of the NCSRP. These documents provide guidance for the assessment and classification of contaminated sites and the establishment of remediation criteria.

The National Classification System of Contaminated Sites is a screening guidance document through which sites can be evaluated and classified as being high, medium or low risk according to their current or potential impact on human health of the environment(CCME 1992). It was developed based on a review of existing international, provincial and territorial methods of classifying contaminated sites, as well as, on an investigation of contaminated sites information available to managers of contaminated sites in Canada. The National Classification System is a stand-alone computer database program to facilitate the efficient storage, retrieval and updating of site classification information.

Interim Canadian Environmental Quality Criteria for Contaminated Sites provide numerical values for the assessment and remediation of soil and water(CCME 1991-1). This document encourages remediation with consideration to the intended land use, technological limitations and other factors. The criteria were adopted from criteria which were in use in various jurisdictions across Canada. They serve as benchmarks against which to assess the degree of contamination at specific sites. Also, they provide a common basis for the establishment of site remediation objectives and verification of the effectiveness of remedial actions.

The Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites has been developed to provide a consistent approach to environmental sampling, analysis and data management for contaminated sites in Canada(CCME 1993-2). It deals with sampling soils, sediments, surface water and groundwater, and recommends analytical procedures for different contaminants commonly found at contaminated sits. The importance of developing and applying quality assurance and quality control measures in sampling, analysis and data management are emphasized throughout the guidance manual.

A Subsurface Assessment Handbook for Contaminated Sites has objective of improving subsurface investigations at contaminated sites(CCME 1994-2). It identifies and describes a sequence of activities that define the subsurface site assessment process. It is emphasized that site assessment is a phased and iterative process(Koo 1996). In the Handbook, contaminants are classified into groups having similar physical and chemical properties, and subsurface conditions are grouped into five broad settings. These contaminant groups and settings provide the basis for defining the contamination concept that should be used to guide all subsurface investigations.

National Guidelines for Decommissioning Industrial Site provide a sequenced approach for assessment and cleanup of contaminated industrial land(CCME 1991-2). The approach is taken to be compatible with intended use of the land.

The assessment and remediation of a contaminated site consist of: 1) site information assessment, 2) reconnaissance testing, 3) detailed testing, 4) preparation and implementation of decommissioning and cleanup plans, 5) confirmatory sampling and completion reporting.

Framework for Ecological Risk Assessment at Contaminated Sites in Canada: Review and Recommendations proposes an approach for evaluation risk to the environment at a specific site(Gaudet 1994). During an ecological risk assessment. bioassays may provide the necessary effect-based information to evaluate the impacts of contaminants to ecological receptors.

These tests are identified in A Review of Whole Organism Bioassays for Assessing the Quality of Soil, Freshwater Sediment and Freshwater in Canada(Keddy et al. 1994). A Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life provides benchmarks of environmental quality required to support protection and management strategies for freshwater, estuarine and marine ecosystems(CCME 1995)

Federal Contaminated Sites

The federal government recognizes that it has an added responsibility to effectively deal with those sites located on federal crown land. This commitment was set forth in the federal

government's Code of Environmental Stewardship, a key component of Canada's Green plan(GC 1990).

Environment Canada has committed $25 million over five years from 1990 to cost-share with other federal government departments for the identification and assessment of high risk contaminated sites located on federal crown land. Remediation is also cost-shared in sites where the polluter cannot be identified(CCME 1994-1, EC 1996).

Memoranda of Intent are required in place between Environment Canada and other participating government departments. The Memoranda of Intent sets eligibility criteria and guiding principles. Environment Canada has signed the Memoranda of Intent with Transport, National Defence, Agriculture, Heritage(Parks), Natural Resources, Public Works and Government Services, Fisheries and Oceans, Indian and Northern Affairs, National Research Council of Canada, and The Royal Canadian Mounted Police. Under these memoranda, more than 230 federal sites have been investigated and remediation has been initiated in more than ten sites that required immediate attention(CCME 1994-1).

Management Scheme of Contaminated Sites

The process of contaminated sites management begins with the identification of sites, as outlined by a generalized regulation/management scheme of contaminated sites in British Columbia, Canada(BCE 1993-2). It is a phased and iterative process that requires many steps of decision-making(Asante-Duah 1996). A site profile is required of various persons. For example, an applicant for municipal approvals, the owner of real property used for specific purposes, or a vendor of commercial or industrial land. The site profile is evaluated in accordance with regulations by an official. The evaluation will determine whether a site should be referred to a Regional Environmental Protection Manager. The site profile will contain readily available information.

A preliminary site investigation and a detailed site investigation may be required by a manager. An investigation requirement may arise from a site profile or other information given by a manager. A report of investigations will be helpful for determining whether a site is contaminated. Provision is made for a preliminary and final determination as to whether a site is contaminated. Subsequently, a manager will notify that independent remediation procedures may occur or a voluntary remediation agreement may be developed without a formal determination.

Responsibility and liability for remediation is to be determined. A relatively broad net of liability may exist. Persons responsible may include current or past owners of a contaminated site or a site from which contamination has migrated. Persons potentially responsible may also include producers or transporters of contaminating substances.

In order to focus liability to achieve fairness and to implement the "polluter pays" principle, conditions are indicated under which persons potentially responsible for remediation would not be liable. Examples of conditions where exemptions may apply include : contamination caused by acts of God or war, a person whose site is contaminated only by migration from another site. Qualification for minor contributor status is provided.

Authority and guidance are provided for determining need and priority for remediation when a manager is considering order. A manager may also delay remediation for reasons of limited risk to health of the environment.

To activate remediation, a voluntary remediation agreement or a remediation order can be used to document responsibility and to set out conditions required to address contamination. A voluntary remediation agreement may be used where a person agrees to responsibility and remediation procedures. A remediation order may be used where a person will not agree to responsibility of remediation requirements.

Once remediation options are evaluated and identified, perhaps in several stages, they may be followed by planning for remediation. Options for effecting remediation are usually several, and one of several combinations may be selected(Koo 1996). Various factors are considered: effects on human health and the environment, technical feasibility and risk, and remediation economics. A preference is given to more practical and permanent solutions. All investigation results, evaluation of remediation options, public consultation input and remediation plans are reviewed, and if it is approved by a manager, it may be culminated in an approval in principle.

Excavation may be required to accommodate underground facilities for development. Relocation of soil, either to a landfill or another site, may in some cases be an acceptable remediation option. Uncertainty, however, often surrounds management of excavated sites(Koo 1996).

Appropriate controls are needed, including the use of standards. Contaminated soil relocation agreements are necessary with the indicated requirements for information on soil quality and environmental conditions at the deposit site. These agreements should provide a more orderly process of managing soils from contaminated sites.

Implementing remediation is defined broadly to cover all stages of site management from preliminary investigations to performance monitoring. However, remediation is commonly viewed more narrowly as the removal or treatment required to clean up or to secure a site to protect the environment, health or property values.

Remediation completion documents are provided to accommodate the broad types of remediation noted above. Certificates of compliance can be issued where numerical standards provided in regulations have been satisfactorily complied with at a site. Conditional certificates of compliance can be issued where risk-based standards and associated assessment procedures have been applied satisfactorily at a site. Notations on the site registry would be required, indicating that certificates have been issued. Confirmatory sampling and analysis to the satisfaction of manager is normally required if a certificate of compliance is to be issued.

Responsibility and Liability for Remediation at Contaminated Sites

For remediation at a contaminated site, the following persons are responsibles:

a) a current owner or operator of the site;

b) a previous owner or operator of the site;
c) a person who produced a substance and, by contract, agreement or otherwise caused the substance to be disposed of, handled or treated in a manner that, in whole or in part, caused the site to become a contaminated site;
d) a person who transported or arranged for transport of a substance and, by contract, agreement or otherwise caused the substance to be disposed of, handled or treated in a manner that, in whole or in party, caused the site to become a contaminated site;
e) a current owner or operator of the site from which the substance migrated;
f) previous owner or operator of the site from which the substance migrated;
g) a person who produced the substance, and by contract, agreement of otherwise caused the substance to be disposed of, handled or treated in a manner that, in whole or in part, caused the substance to migrate to the contaminated site,
h) a person who transported or arranged for transport of the substance and caused the substance to be disposed of, handled or treated in a manner that caused the substance to migrate to the contaminated site,
i) a secured creditor who exercised control over or imposed requirements on any person regarding the manner of treatment, disposal or handling of a substance and the control or requirements caused the site to become a contaminated site or becomes the registered owner in fee simple of the real property at the contaminated site(BCE 1993-1)

General principles of liability for remediation are as follows:
a person who is responsible for remediation at a contaminated site is absolutely, retroactively and jointly and severally liable to any person or government body for reasonably incurred costs of remediation of the contaminated site, whether incurred on or off the site. Costs of remediation include, without limitation, costs of preparing a site profile, costs of carrying out a site investigation and preparing a report, legal and consultant costs associated with seeking contributions from the responsible perons, and fees imposed by a manager, a municipality, and approving officer(BCE 1993-1).

Any person who fails to submit a site profile to undertake a preliminary site investigation or a detailed site investigation, to prepare a report of the investigation, to comply with a remediation, to seek an opinion from an allocation panel, to comply with the terms and conditions required by a manager in a voluntary remediation agreement, to notify a manager of independent remediation, and to comply with requirements of a manager regarding independent remediation, and any person who relocates contaminated soil without a contaminated soil relocation agreement will commit an offence and be liable to a penalty not exceeding $200,000(BCE 1993-1).

Development and Demonstration of Site Remediation Technologies

Canada has allocated $50 million to the Development and Demonstration of Site Remediation Technology(DESRT) as a component of the NCSRP(CCME 1994-1; EC 1996). The DESRT has been devoted to the development of new technologies in the areas of site

characterization, assessment, remediation and compliance monitoring. It was established to address the NCSRP objective of working with industry to the potential to resolve problems that are critical to the environmental remediation of contaminate sites.

Funding has been available for solicited and unsolicited proposals according to two levels of priorities. First priority is given to projects designed to demonstrate promising new technologies that have been developed to the pilot plant stage, but require on site field evaluation to verify performance and cost information. Second priority is reserved for projects designed to advance technologies that are in the laboratory stages of development. Funding has been negotiated on a case-by-case basis determined by the potential environmental benefits, and the degree of technological risk.

The DESRT has represented an unprecedented opportunity for the Canadian environmental industry to take the initiative in developing world-class remediation technologies. Incorporated companies, universities, municipalities, trade and research organizations and consulting firms with demonstrated competence in the environmental technology are eligible to apply for the funding.

Eligibility criteria for individual projects include: involvement of the applicants in the remediation of contaminated sites, project goals directed toward the development and/or demonstration of new and improved technologies to reduce or eliminate threats posed to human health or the environment by contaminated sites, the uniqueness of usage of the technology and its potential for application across Canada or within a restricted area where a serious problem may exist, and the presence of considerable technological risk in achieving commercialization of the technology.

Demonstration projects are defined as the inaugural field application of a new technology at pilot or prototype scale. Research and development projects support the evolution of technology in the laboratory to the point that technical feasibility is established. The DESRT supports a share of the total estimated costs of approved projects. Decisions on the appropriate share are negotiated on a case-by case basis.

Technology ownership rights are among the topics negotiated in reaching a contractual agreement. All contractors receiving financial support from the DESRT are required to provide a comprehensive final report on the project. Consistent with the contractor's proprietary rights, testing evaluation data contained in the final report may be used by the DESRT to transfer information on new technologies to all interested parties throughout Canada, Contractors may be required to present a paper on their work at a designated technology transfer symposium.

More than 35 DESRT projects were initiated under the NCSRP(CCME 1994-1).

Remedial Technologies for Contaminated Sites

Many conventional and innovative technologies are available nowadays for the remediation of contaminated sites. These technologies are reviewed by Koo(1996).

The following represents important DESRT-supported technologies:

1) mobile thermal phase separation conducted in Alberta and Newfoundland by TriWaste to

remediate PCB-contaminated soils;
2) reductive dechlorination and enhanced bioremediation of herbicide/pesticide-contaminated soils and sediments in Ontario by Grace Dearborn;
3) bioventing, air sparging, air-water separation, trickling filter reactor and biofilitration by Biogenic to remediate the contaminated soils surrounding and underground storage tank in Quebec;
4) bioreactor by Nevis to remediate hydrocarbon and brine contaminated soil from a pipeline break in Alberta;
5) in-site and ex-situ bioremediation of soils containing cholorphenols and polynuclear aromatic hydrocarbons in Ontario by Grace Dearborn;
6) integration of enhanced oxidation(UV, hydrogen peroxide, ozone)and sonic mixing for the treatment of contaminated soil by ARC Sonics in British Columbia;
7) composting bioremediation of hydrocarbon impacted soils by CBCL in Prince Edward Island;
8) enhanced sequential anaerobic-aerobic bioremediation by Grace Dearborn to treat soil contaminated with coal tar which contained DNAPLs, PAHs and TPHs in British Columbia: aerobic/anaerobic soil remediation at a creosote/PCB-contaminated site in Saskatchewan by Sentar;
9)air sparging, vapor extraction system by ADI at a petroleum contaminated site in New Brunswick;
10) tracers/peat moss biofilter by GEMETEC in New Brunswick;
11) stabilization/solidification with cementitious binders by WTC in Ontario;
12) mobile ex-site bioreactor by NER to remediate hydrocarbon contaminated soil in Ontario;
13) near-real time analytic techniques by ASL for remediation of contaminated soils in British Columbia;
14) in-situ remediation of soils by venting and forced aeration at Shell Service stations in Quebec by Shell and ADS;
15) in-situ bioremediation followed by solidifications to treat soils contaminated by hydrocarbons and other pollutants in Quebec by Sanetex;;
16) flotation separation treatment for soils contaminated with heavy metals in Quebec by Tallon;
17) vacuum pyrolysis to remediate soils contaminated with hydrocarbons, PAHs, and PCBs in Quebec by Laval University and IP;
18) biopiles to treat soils contaminated with diesel fuel and transformer oil in Quebec by Biogenic;
19) pervaporation of VOC at a hydrocarbon contaminated site in Ontario by Zenon;
20) enhanced microbial population growth to remediate wood preservertives site in Alberta by ARC;
21) self sealing and self healing containment system by WTC in Ontario;
22) soil treatment by Tallon for various target metals and PAHs at the Attari site that was used for foundries, scrap yards, rail lands and coal yards near Toronto in Ontario;
23) in-situ/on-site bioremediation of wood treatment soils containing chlorinated phenols and PAHs in Ontario by Grace Dearborn;
24) soil washing and bio-slurry reactor for PCB-heavy metal contaminated soils in New Brunswick by Washburn&Gillis;
25) lignin-degrading white rot fungi used to treat PAH-contaminated soils in New Brunswick by NBRPC;

26) gravel washing at the Canada Creosote site in Alberta by ARC and Acres; soil washing by Klohn-Crippen to remediate soils contaminated with wood preservatives in British Columbia;
27) stabilization/solidification(portland cement and sodium silicates by Bovar and Chem-Security; fly ash and portland cement by Wastech/Waste Stream and Newalta; portland cement and pozzolans and other additives by CWW; calcium and polysilicate-based reagents, organic binding reagents and precipitating agents by Ogden and Chemfix; organic binding reagents and precipitating agents by Ogden and Chemfix; portland cement, fly ash and aluminosilicate by Bennett/Portland);
thermal extraction(low temperature fired rotary dryer and nitrogen by CWM, pyrolysis and distillation by Newalta/UMATAC);
bioremediation(aerobic slurry phase by CWM, slurry and solid phases by Chem-Security and RT; bioaugmented solid phases by Waste Stream) to treat soils contaminated with PAHs, chlorophenols, cyanide, heavy metals, and other contaminants at the Pacific Place site which housed gas plants, rail yards, wood treatment facilities, metal works, fuel storage/transfer facilities and other industrial facilities in Vancouver, British Columbia;
28) ex-situ electrokinetics by Lupien Rosenberg and in-situ electrokinetics/bioremediation by McGill University and the City of Montreal to treat heavy metal contaminated soils in Quebec;
29) surfactants for enhanced recovery of organic contaminants at the Ville Mercier orphan site in Quebec by Laval University;
30) horizontal wells, air sparging, bioventing, soil vapor extraction in a simultaneous manner at the petroleum-contaminated orphan site at Gander, Newfoundland by Jacques Whitford(DESRT 1993-1995).

Conclusions

A comprehensive societal strategy is necessary to integrate all aspects of environmental protection. It can be achieved on the basis of action for the remediation of contaminated sites(soil, water and air) and holistic-phased decision-making methodologies. These can provide a globally consistent approach for the contamination discovery, characterization, risk assessment and cleanup action.

Contaminated sites present a two-sided problem: one side is the problem of existing contaminated sites, while the other side involves the prevention of future site contamination. Both sides are equally important.

Environmental liability of preventing contaminated sites should be considered important in accordance with the globally accepted "precautionary principle". An integrated principle of "sustainable development, polluter-pays, beneficiary-pays, and fairness' should be supported in any contaminated site remediation policy and legislation. The concepts of openness, accessibility and participation should prevail in the contaminated site remediation process.

A proper integration of available technologies can lead to new methods for more effective treatment of soil and groundwater in contaminated sites. Every effort should be exercised to utilize integrated technologies to achieve the highest levels of efficiency for the remediation of contaminated sites

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