Five-year review of the Canada-Wide Standards for Petroleum Hydrocarbons (PHC CWS):

Ecological, Direct Soil Contact Guidance

1. Introduction

Canada has been among the first of jurisdictions to develop a set of consistent, generically applicable, environmental (ecological and human health) risk-based assessment and remediation guidelines for refined and unrefined petroleum hydrocarbon releases to soil ecosystems. Canada-Wide Standards for Petroleum Hydrocarbons **(PHC CWS)** were developed in 1998-99, based on significant new approaches and new scientific studies on both human health effects and effects on soil productivity and ecological functioning. The PHC CWS are intended to address risks from: hydrocarbon releases to human health; to aquatic life based on groundwater-mediated transport of hydrocarbons; to livestock in agricultural systems; and, in particular, to agronomic plant productivity or plant community 'health' in non-agronomic settings. The PHC CWS were also intended to address risks to soil microarthropods and various other soil fauna that are considered to be important in maintaining a minimum level of soil ecological functioning.

During the initial development of the PHC CWS, the PHC CWS Development Committee was lead by Alberta as the Champion for this Canada-Wide Standard[1]. The Canada-Wide Standards development and implementation was facilitated, in part, through the Canadian Council of Ministers of the Environment **(CCME)** framework. The PHC CWS Development Committee was assisted in the initial development of the PHC CWS by input from three multistakeholder technical expert groups, each with representation from academia, the oil and gas sector, environmental consulting sector, and environmental regulators. The groups included the following:

- Human Health, Fate and Transport Technical Advisory Group **(HHFTTAG);**
- Ecological Technical Advisory Group **(EcoTAG);**
- Analytical Methods Technical Advisory Group **(AmTAG).**

The reader is referred to CCME (2000, 2001 a,b) for an account of the scope of discussions, group representation, issues discussed, critical decision points, and outcomes of deliberations.

Several aspects of the PHC CWS made it ground-breaking in nature, but at the same time stimulated a desire to assess the extent to which they accomplished their intended objectives within the initial years; i.e., protection of human health and the environment, for cases where petroleum hydrocarbons had been released to the environment. Ideally, such protection should be enacted in a manner that strikes a balance between the degree of uncertainty about concentration-effect relationships and the desire to avoid a financial burden beyond what may be required to resolve the actual environmental risks.

A major aspect of the PHC CWS was the establishment of an operational definition of petroleum hydrocarbons that was intended to accommodate known differences in the types of petroleum products potentially released to the environment, as well as significant differences in their expected volatility, aqueous solubility, persistence in soil systems, and partitioning into organic-carbon and lipid-rich matrices (including living organisms). Four PHC CWS fractions were established, as follows:

[1] During the same period, Canada-Wide Standards were also developed for dioxins/furans, benzene, ground level ozone, particulate matter, and mercury. These five CWS are based largely on source inventories and source control measures, whereas the PHC CWS is unique in being a set of soil quality standards to provide the mechanism for standardized approaches across Canadian jurisdictions to hydrocarbon releases.

- **CWS Fraction 1 (F1):** all aliphatic, aromatic, and assorted petroleum-based hydrocarbons with an effective boiling point range that results in elution on a GC column based on boiling point separation between the peak of *n*-hexane (*n*C6) and *n*-decane (*n*C_{10}). Exceptions to this are the compounds benzene, toluene, ethylbenzene, and xylenes (BTEX compounds), which are separately managed using CCME soil quality guidelines and/or provincial soil standards or guidelines.

- **CWS Fraction 2 (F2):** All petroleum-based hydrocarbons as above with an effective boiling point range between *n*-decane (*n*C_{10}) and *n*C_{16}, excluding naphthalene.

- **CWS Fraction 3 (F3):** all petroleum-based hydrocarbons as above with an effective boiling point range bounded by the elution peak of *n*C_{16} and *n*C_{34}.

- **CWS Fraction 4 (F4):** all petroleum-based hydrocarbons as above with an effective boiling point range greater than *n*C_{34}.

Fresh motor gas (mogas) releases fall primarily within the F1 range, with lesser amounts of F2. Diesel and heating oil composition typically spans F2 and F3. Asphaltenes and many of the residual products of heavy crude releases to soil after weathering in the environment fall within the F3 and F4 range.

The four PHC CWS fractions were derived based in large part, on extensive prior scientific review and analysis of petroleum product composition, hydrocarbon fate, and human toxicity thresholds, originally undertaken in the United States by the Total Petroleum Hydrocarbon Criterion Working Group **(TPHCWG).** The four PHC CWS fractions are a “roll-up” of the 17 TPHCWG sub-fractions.

Because the PHC CWS four fractions comprised a new operational definition to both science and the environmental regulation of petroleum hydrocarbons, the scientific literature provided very few toxicity data that were useful for establishing soil guidelines that would be effective for soil invertebrate and plant protection based on direct contact. The PHC soil quality guidelines developed, therefore, were based almost entirely on a set of new laboratory-based, soil ecotoxicity studies conducted by ESG (now Stantec), with support from the Petroleum Technology Alliance of Canada, through its funding partners, including the Canadian Association of Petroleum Producers (CAPP), Canadian Petroleum Products Institute (CPPI), Alberta Environment (AENV) and others. Some data were available through studies supported by the Quebec Ministry of Environment and Environment Canada. In addition, syntheses of the new ecotoxicity data were critically evaluated in light of existing studies on the effects on individual (surrogate) compounds or whole product releases (crude, diesel, naphtha, etc.) on soil flora and fauna.

The new ecotoxicity data were developed using a laboratory fractionated, fresh, relatively sweet crude oil (Whole Federated Crude) from an Alberta source, as well as two soil types – an artificial (OECD) soil, and a field-collected, relatively fine-textured Chernozem loam. Virtually all ecotoxicity data for CWS fractions generated since 1999 is based on this particular petroleum source. Some additional data exist, using the same test species and similar test methods, for motor gasoline (mogas). There remains concern that the fresh crude represents a narrow range of composition relative to the expected types of petroleum hydrocarbon releases that must be effectively managed in Canada. The combination of the limited number of species used to develop the toxicity data (all best suited to agronomic settings), limited range of product types examined toxicologically, and limited types of soils used in laboratory toxicity tests have been criticized as a large source of uncertainty for management of the risks associated with soil contamination.

When the PHC CWS was endorsed by the Federal, Provincial and Territorial Ministers of the Environment, in 1999, it was considered prudent to formally include a five-year review, which would take advantage of new scientific/technical information that was expected to come to the fore in light of the new management regime, as well as effort given during the development process to identifying scientific data gaps. In preparation for this five year review, the CCME Soil Quality Guidelines Task Group **(SQGTG)** in 2004, sponsored the review of new relevant scientific research and development work completed since 1999 (Tindal and Bright, Mar. 2004).

Further to the analysis in the Tindal and Bright (2004) report, the SQGTG began in earnest an extensive review of the PHC CWS in early 2005. To assist them with their review, the SQGTG convened a technical working group, the **"Ecological Criteria Advisory Sub Group" (EcoSG)** to assist with critical evaluation of the scientific basis, validity, and accuracy of PHC soil guidelines developed in consideration of effects on plants and soil fauna based on direct contact exposures in surface soil systems[2]. **This report provides a summary of the deliberations and recommendations of the EcoSG[3].**

Individuals who contributed to the review and revision of the Petroleum Hydrocarbon Canada-Wide Standards through their participation in the EcoSG are listed in Appendix A.

1.1 Objectives

The deliberations of the EcoSG were guided initially by a Terms of Reference **(ToR:** Appendix B). The scope of discussions and analysis was initially narrowed by the SQGTG in reflection of the previous review (Tindal and Bright, 2004), as well as extensive informal consultations with various stakeholders regarding priority issues, and the major drivers for site assessment and remediation based on the previous, approximate five years of experience.

For example, managing risks of F1 hydrocarbons in subsurface soils below impervious surfaces remains a significant issue in urbanized environments at gas stations and other locations where leaking underground storage tanks have been identified. Soil standards for CWS Fraction F3 from crude oil releases are of particular interest for environmental practitioners and stakeholders in rural or undeveloped areas, in light of the extensive observations that (i) F3 potentially encompasses a wide range of different compounds; (ii) the higher molecular weight compounds in this fraction are more recalcitrant to microbial biodegradation in soils or volatilization; and

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[2] The potential for risks to soil-dwelling organisms from petroleum hydrocarbon contaminated soils is predicated on a viable exposure pathway; i.e., presence of contaminants within the potential rooting or burrowing zone. In the 1999 PHC CWS (CCME, 2000), management/remediation objectives were established for sub-surface soils that were based in part on protection against risks to soil invertebrates and plants. This is discussed farther on in the report.

[3] In addition to the EcoSG, several other technical working groups were tasked by the SQGTG to work concurrently on other aspects of the PHC CWS such as indoor intrusion of contaminated soil vapours, predicting groundwater mediated exposures, and human toxicity reference values. Interested readers are referred to reports by the other technical sub-groups.

(iii) there may be significant potential for a lower realized toxicity for weathered, aged releases, owing to limited bioavailability.

On the basis of the above referenced review scope considerations, the objectives of the EcoSG were the following:

- Briefly review the Terms of Reference and propose changes with an accompanying rationale;

- Undertake scientific reviews of critical issues of relevance to understanding and managing risks to soil invertebrates and plants exposed to petroleum hydrocarbon mixtures in soil;

- In light of the best available scientific information, review the existing PHC CWS in terms of their derivation particulars as well as the realized level of biological effects, especially in field studies, relative to narrative protection goals;

- Propose changes to the existing generic soil quality guidelines, as appropriate, and provide a clear and unequivocal scientific rationale;

- Identify those critical components of the soil quality guideline development that may require policy decisions from the SQGTG; and,

- Assist with development of further site-specific approaches to addressing petroleum hydrocarbon risks to soil systems.

Environmental management approaches invariable require simplication of what is typically complex underlying scientific information, including large areas of uncertainty and unknowns, detailed deliberations around mitigating factors or confounding influences of cause-effect relationships, and a rapid state of flux in the knowledge base. The requisite guidance is strengthened to the extent that there is greater scientific consensus around and issue, and resultant reduction in the uncertainty about the outcome of a proposed approach or use of a particular tool.

As such, the EcoSG strove to provide the SQGTG with clear guidance by advancing those pertinent issues and the suggestions for guideline revisions that were based on consensus. Several innovative and at times speculative approaches came to light in the discussions that – while fertile ground for scientific research – were deemed to be too immature to assist with pragmatic management approaches. In a few specific cases, the EcoSG has recommended adoption of an approach for the specific purpose that we felt it would serve as a strong catalyst for studies that may have concrete management utility within the next 5-10 years.

The EcoSG deliberations and recommendations fell into two broad areas:

- A major priority was the critical evaluation of the existing generic numerical soil quality standards in light of discussions since 1999, on soil quality guideline derivation protocols in Canada, results from field studies of experimentally oiled soil plots, concerns raised in recent years regarding particulars of the original derivation, and new ecotoxicity data produced since 1999. The major sub-text to these deliberations was based on the questions: “Did we get it right? Is there evidence that the existing generic soil standards are inadequately protective in some circumstances? Conversely, are the existing guidelines overly protective (unnecessarily conservative) in some circumstances? Has our knowledge changed sufficiently since 1999-2000 to justify a change to the generic PHC soil quality standards?

- The second major area of focus was the possible development of approaches that might be used in Canadian jurisdictions for developing more site-specific site assessment and remediation objectives in consideration of ecological direct soil contact exposures in cases where use of generic soil standards might be inappropriate. The terminology that has been utilized by the CCME to describe a structured access to different levels of investigative effort at a site en route to implementing risk management solutions is as follows: Tier 1 - development and use of generic numerical environmental quality guidelines (including the PHC CWS); Tier 2 – incorporation of more site-specific information toward a re-calculation of numerical environmental quality guidelines (typically in the past by replacing assumed site characteristics with measured site characteristics, in cases where contaminant concentrations at the point of exposure were estimated with a predictive model); and Tier 3 – detailed quantitative human health and ecological risk assessment, the methodology for which is highly tailored to site conditions.

  The EcoSG was specifically tasked with evaluating options for and the issues associated with possible Tier 2 approaches for the ecological direct contact pathway. As discussed in subsequent chapters, the focus of Tier 2 deliberations was on the use of ecotoxicity tests to develop site-specific remediation objectives, and methods that might estimate degree of bioavailability from soil.

1.2 Report Structure

The remaining sections of this report are structured as follows:

Section 2: Summary of Major Outstanding Scientific/Technical Issues for the PHC CWS Ecological Direct Contact Standards, and Scope of the EcoSG Deliberations

Section 3: Background Information – Relevant CCME/CWS Environmental Protection Goals

Section 4: Review of the Generic Numerical (Tier I) Soil Standards for Protection of Soil Invertebrates and Plants

Section 5: Development of Tier 2/3 Approaches for PHC Contaminated Sites.

Section 6: Continuing Knowledge Gaps

Section 7: SQGTG Policy Decision Requirements

Section 8: Summary Recommendations of the EcoSG

Section 9: References Cited