HISTORICAL PERSPECTIVE: SETTING SOIL CLEANUP LEVELS IN THE U.S.

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KEYWORDS: soil, petroleum, risk assessment, soil ingestion, TPH

While scientific, governmental and public concern in the U.S. for the contamination of the nation's waterways and air have had a long standing history and flourished in the 1960's and 70's, soil as a contaminated media was all but ignored until the mid-1980's. Water protection legislation began with the River and Harbor Act (1898) and evolved over the next century into the Water Pollution Control Act (1948), Water Quality Act (1965), the Safe Drinking Water Act (1974) and Clean Water Act (1977). The Clean Air Act which was enacted in 1970 to control atmospheric pollution help stem the degradation of the nation's air quality. As in the case of water, legislation protecting air quality began in the 1890's with the passage of several smoke emission controls at the state level.

Legislative protection of soil at even the state level has a more abbreviated history and no such specific national legislation as a "Clean Soil Act". The principal impetus for the protection of soils comes indirectly from two pieces of federal legislation: the Resource Conservation and Recovery Act (RCRA) (1976) and its Hazardous and Solid Waste Amendments (1984) (U.S. EPA 1990), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or SUPERFUND) (1980) (U.S. Congress 1980). RCRA was enacted to regulate hazardous wastes from their generation through their disposal and to protect the groundwater aquifers from the land disposal of hazardous wastes. CERCLA was enacted to cleanup abandoned and inactive hazardous waste sites. Neither act specifically addressed soil contamination, but each provided the framework for soil contamination to be considered, as a hazardous waste with respect to RCRA and an imminent and substantial danger to the public health and welfare with respect to CERCLA.

One component, in particular, of the Hazardous and Solid Waste Amendments of 1984 which helped focus attention on soil contamination was the inclusion of the regulation of underground storage tanks. This action helped bring the issue of leaking underground storage tanks (LUSTs) to the public's attention which ultimately increased governmental action to cleanup contamination at these sites. Initially remedial efforts focused on groundwater contamination and pump and treat technologies. By the late 1980's and early 1990's an overwhelming consensus had emerged amongst regulators and environmental professionals that the source (i.e. contaminated soil) at LUST sites needed to be included in an overall remediation strategy to enhance cost effective approaches to the cleanup of contaminated sites.

Surveys of states in the U.S. performed in the 1980's indicated that approaches to the cleanup of LUST sites and petroleum contaminated soils varied with respect to consistency, comprehensiveness, and sophistication (Kostecki *et al.* 1988). In 1985, no state had a comprehensive plan or policies to determine acceptable levels of contamination or allowable cleanup technologies. This led to confusion on the part of both regulators and the private sector.

One reason for the confusion with regard to petroleum contaminated soils laid in the interpretation of RCRA. Petroleum products were not listed as hazardous waste and specifically exempted under RCRA and therefore some states did not did not considered petroleum contaminated soils as hazardous waste. Petroleum products were also exempted from CERCLA. However, some chemical constituents of petroleum products such as benzene, toluene, and xylene were considered hazardous under RCRA. Some states applied the logic that petroleum products that contain any hazardous constituents are to be considered as a hazardous waste themselves. Still other states believed that for petroleum contaminated soils to be considered hazardous under RCRA they must exhibit the characteristics outlined in RCRA. That is, ignitability, corrosivity or EP toxicity. However, ignitability and corrosivity cannot be applied to a soil matrix and the EP toxicity test was developed to assess the quality of landfill leachate with respect to metals and pesticides and clearly irrelevant to petroleum contaminated soils.

The use and acceptance of risk assessment to establish contaminant levels protective of human and ecological health was consolidated with the publication of the National Academy of Sciences committee report, *Risk Assessment in the Federal Government: Managing the Process* (NRC 1983). The report identified the now universally recognized four-step framework for characterizing the likelihood of adverse health effects from particular chemical exposures, namely hazard identification, dose-response assessment, exposure assessment and risk characterization.

The application of the risk assessment process in establishing petroleum contaminated soil cleanup levels was first reported in the literature by Stokman & Dime (1986) who used a variety of assumptions and a simple risk assessment approach to determine that soil cleanup levels of 100ppm Total Petroleum Hydrocarbons (TPH) would not exceed a 1×10^{-6} cancer risk when applied to gasoline spills. This approached was flawed, however, by the use of TPH as the measurement unit and the assumption that the chemical composition of the gasoline product was the same as the chemicals present in the soil matrix of a spill. Regular analytical procedures for the determination of TPH do not distinguish between the wide variety of possible hydrocarbons each of which present different health hazards. The use of TPH as a risk-based cleanup standard was successfully addressed by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) in the early 1990's and is discussed later.

The Council for the Health and Environmental Safety of Soils (CHESS) was established in 1988 by the Society for Regulatory Toxicology and Pharmacology and funded primarily by USEPA the Agency for Toxic Substances and Disease Registry (ATSDR) to develop an advanced risk assessment model for petroleum contaminated sites. The Council's efforts resulted in a comprehensive review of available risk assessment approaches (Calabrese and Kostecki 1992) and recommendations for appropriate environmental fate models and a number default exposure parameters.

Two other groups contributed significantly to the use of risk-based approaches to establish soil cleanup levels: the TPH Criteria Working Group (TPHCWG) and ASTM. The TPHCWG convened in 1993 to address the large disparity among cleanup requirements used by states at sites contaminated with petroleum fuels and the fact that TPH, as it was being used, was not a scientifically sound, health-based standard. The Working Group's approach which culminated in the derivation of fate and transport fraction toxicity criteria represented a scientifically defensible technical basis for risk based corrective actions using TPH values. The TPHCWG compiled their work in a five-volume set published in 1998 (TPHCWG 1998) and has been accepted at the state and federal level in the U.S..

ASTM developed a risk-based corrective action process (RBCA) which is the integration of site assessment, remedial action selection, and monitoring with appropriate risk and exposure assessment practices. The process is three tiered using non-site-specific human health risk-based values for chemicals of concern in Tier I, progressing to Tier III with the inclusion of more site-specific data and advaned exposure assessment, toxicity and risk assessment techniques (e.g. probabilistic exposure methods, use of bio-availability data and fate and transport modeling). Both TPHCWG and ASTM efforts have helped solidify the use of risk assessment in establishing soil cleanup level.

Clearly, the 90's have been the decade of human and ecological risk assessment with respect to the cleanup of contaminated sites in the U.S. Today the determination of "safe levels", action levels, cleanup levels, etc. are usually made by characterizing the risks associated with chemical contamination using the basic approach outlined in the NRC (1983) report or some modification. However, the 'driver' for most contaminated soil cleanups, especially Superfund cleanups, is the exposure assessment component or the determination of the conditions under which receptors such as humans could be exposed to contaminants and the doses that occur as a result of such exposures.

One of the most important pathways of exposure when evaluating risks posed by contaminated soil is incidental soil ingestion. Soil ingestion as a possible pathway of exposure has been studied since the mid-1980's (Binder *et al.* 1986) and extensively studied by Calabrese and his colleagues at the University of Massachusetts since the mid-1980's (Calabrese *et al.* 1999). Of particular significance is that such work has begun to define the occurrence soil ingestion behavior in normal children in the ages from 1 to 7 years. This work has begun to define the distribution of soil ingestion in children including the measure of central tendency and the upper portions of the exposure range (95^{th} to 99^{th} %). In addition, this work has developed soil ingestion estimates on a daily basis that have the potential for incorporation into sophisticated Monte Carlo estimates. Further analyses were able to distinguish soil ingestion from dust ingestion and to apply those findings to the indoor and outdoor environments.

More recent investigation has been able refine the assessment further by identifying the particle size that individual children have ingested on specific days. Since numerous contaminants adhere to soil particles of a particular particle size range, this later development offers exciting possibilities for refining site-specific soil ingestion estimates as well as contaminant specific exposure estimates. Despite these advances in the development of soil ingestion methodologies and their applications, it should be emphasized that the current collective database of soil ingestion studies are generally relegated to a single season of the year (i.e. late summer - fall); have never addressed the issue of the extent of ground cover (e.g. grass) on ingestion rates; have never estimated soil ingestion in urban children, adults or site workers; and have only estimated soil ingestion in children with normal or average soil ingestion estimates despite reliable evidence of high ingesting children (i.e. pica 5 to 30 grams of soil per day).

With respect to soil pica children, a recent study by Calabrese et al has suggested that the consumption of some contaminants from soil at concentrations equal to acceptable EPA Soil Screening Levels may pose a threat of lethality. The issue raised here is that past soil cleanup standards have been directed principally toward prevent chronic adverse health effects (i.e. cancer) while ignoring acute potential effects that could occur in soil pica children. Knowing the frequency of soil pica and its variability amongst such affected children represents an important public health priority. These later limitations in the soil ingestion research especially for soil pica children represent significant public health questions that need to be addressed by the research community in order to improve the accuracy of exposure assessments and the risk assessment process in general.

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