OAKLAND BENZENE PARTITIONING STUDY

SYNOPSIS

L. R. Spence and M. M. Gomez

Background

The Oakland benzene partitioning study was conducted as part of the City of Oakland Urban Land Redevelopment (ULR) Program.[1] The centerpiece of the ULR Program is a set of look-up tables that provide risk-based corrective action (RBCA) levels appropriate for contaminated sites in Oakland. These RBCA levels are calculated using Oakland-specific geological, hydro-geological and climactic data in a modified American Society for Testing and Materials (ASTM) RBCA model.[2]

Fraction organic carbon in soil (F_{oc}) is included as an input parameter in the ASTM RBCA model because it has a major impact on the ability of organic chemicals to sorb to soil. The model's equations assume that the mathematical product of F_{oc} and the octanol water partition coefficient (K_{oc}) equals the distribution coefficient (K_d). (K_d is defined as the ratio of the sorbed chemical concentration to the dissolved-phase chemical concentration.) Although F_{oc} is known to be an important contributor to sorption, it is only a partial predictor of the total sorption that occurs.

The ULR Program Technical Advisory Committee[3] concluded that the Oakland RBCA model should take into account the fact that mineral surfaces, such as clay, and electromagnetic molecular forces also cause chemicals to sorb, even if no organic carbon is present.[4] To account for these additional processes, a new input parameter, F_{oc}*, was introduced to replace F_{oc} in the Oakland RBCA equations. The objective of the Oakland study was to quantify this F_{oc}* value by measuring the partitioning[5] of benzene in the three soil types addressed in the Oakland look-up tables: Merritt sands (a fine-grained, silty sand), sandy silts, and clayey silts.

Methodology

Sampling Protocol

Soil samples were collected from 30 locations throughout Oakland. Sampling locations were not selected randomly. Site selection was influenced by the following:

1. To avoid difficulties associated with site access and liability, all sites selected were owned by the City or Port of Oakland.
2. Every effort was made to collect ten samples each from the soil types addressed in the Oakland RBCA model: Merritt sands, sandy silts, and clayey silts. Sites were chosen accordingly. The selection process relied on (1) the accumulated knowledge and field experience of City of Oakland Environmental Services Division staff and local environmental consultants under contract to the City; (2) information provided to the City by Port of Oakland environmental scientists; and (3) geologic information collected and reported by the United States Geological Survey.[6]
3. Sample locations were distributed geographically throughout Oakland to ensure that soils from all areas of the city were represented.

4. Samples were taken only from sites reasonably assumed to be free of contamination to limit the potential for anthropogenic chemicals to influence the observed organic carbon levels.

Of the 30 samples collected, 13 exhibited physical characteristics associated with Merritt sands, 10 associated with sandy silts, and 7 associated with clayey silts.[7]

Analytical Approach[8]

All 30 samples were analyzed for particle size and organic carbon. Of the 30 samples, six were selected for measurement of the benzene distribution coefficient, two from each of the three soil types. Samples were selected to be representative of the range of particle size and F_{oc} values found to be associated with each soil type.

The six soil samples were sieved through 1 millimeter mesh sieves to remove large particles and gravels from the sediments. The six sediment samples were tested for benzene sorption in zero-headspace glass vials with Teflon caps. Two replicates of ten grams of each sediment were equilibrated with approximately 30 ml of aqueous benzene solutions containing 5, 10, 25 and 60 mg/l concentrations of benzene, and allowed to equilibrate for 24 hours with periodic gentle mixing. Samples were then centrifuged and decanted into Teflon-capped sample vials and sent to a laboratory for analysis. The slope of the adsorption isotherm was calculated from plots using the solid concentration of benzene (reported as mg of benzene per g of soil) on the y-axis, and the equilibrium concentration of benzene in solution (reported as mg of benzene per ml of solution) on the x-axis. The slope of this plot is the distribution coefficient for benzene, K_d, measured in ml of solution per g of soil.

An F_{oc}* value was calculated for each sample by dividing the observed K_d of each sample by the benzene-specific K_{oc} value of 58.9 ml/g.[9]

Results

The reported benzene distribution coefficients revealed that, for all soil types, the sorption observed exceeded the amount that would be predicted if the measured F_{oc} were the only factor considered to affect sorption. In addition, the observed K_d did not decrease commensurately with decreases in F_{oc}. These results indicate that factors other than F_{oc} contributed significantly to sorption. Table 1 summarizes all the study results.

Table 1. Summary of Benzene Partitioning Study Results

Sample	Soil Type	F_{oc} (g/g)	K_d ([mg/kg]/[mg/l])	Estimated F_{oc}* (g/g)
1	Merritt sands	0.00354	0.960	0.0163
2	Merritt sands	0.00468	0.534	0.0091
3	Sandy silts	0.00418	0.923	0.0157
4	Sandy silts	0.00712	0.932	0.0158
5	Clayey silts	0.01490	1.262	0.0214
6	Clayey silts	0.01736	1.290	0.0219

Conclusions

Appropriate F_{oc}* values for the three soil types addressed in the Oakland RBCA model may be recommended based on the F_{oc}* values presented in Table 1. Table 2 presents the recommended F_{oc}* values.

Table 2. Recommended F_{oc}* Values for Predominant Oakland Soil Types (g/g)

Merritt Sands	Sandy Silts	Clayey Silts
0.010	0.015	0.020

The F_{oc}* value may be used in the Oakland RBCA model to predict the amount of sorption that occurs in each soil type. The Oakland RBCA model will still predict a unique level of sorption for each chemical of concern because unique K_{oc} values are included for each.

The recommended F_{oc}* values represent the best analysis of available data based on the limited scope of this study.

---

[1] The City of Oakland Urban Land Redevelopment Program is funded through a grant from the United States Environmental Protection Agency, Region 9, Office of Underground Storage Tanks.

[2] American Society for Testing and Materials, 1995, *Standard Guide to Risk-Based Corrective Action Applied at Petroleum Release Sites*, ASTM E1739-95.

[3] The ULR Program Technical Advisory Committee consists of representatives from: U.S. EPA, Region 9; Department of Toxic Substances Control; San Francisco Bay Regional Water Quality Control Board; Alameda County Department of Environmental Health; City of Oakland; and volunteer environmental consultants.

[4] Knox, R.C., Sabatini, D.A., and Canter, L.W, 1993, *Subsurface Transport and Fate Processes*, Michigan: Lewis Publishers; Lyman, W.J., Reidy, P.J., and Levy, B, 1992, *Mobility and Degradation of Organic Contaminants in Subsurface Environments*, prepared for the U.S. EPA, Michigan: C. K. Smoley, Inc.

[5] The Oakland study isolated the sorption phase of the partitioning process for measurement.

[6] Radbruch, D. 1957, *Areal and Engineering Geology of the Oakland West Quadrangle, California*, United States Geological Survey.

[7] *Oakland Risk-Based Corrective Action: Technical Background Document*, available from the City of Oakland Environmental Services Division, provides the general characteristics of each of these soil types.

[8] Laboratory analyses were performed by SECOR International, Inc., contractor to the City of Oakland.

[9] U.S. EPA, 1995, *Soil Screening Guidance*, Office of Solid Waste and Emergency Response, EPA/540/R-94/101.