Appendix G

Chemical Specific Soil Half-Lives

Appendix G

Chemical-specific Soil Half-life

G.1 Metals

Biodegradation as such is not expected to occur with metals and other elements because of their elemental nature. Therefore, as a default estimate the metal content of soil is assumed to decay with a half-life of 10^8 days unless site-specific information is presented showing that soil conditions will result in the loss of soil metal content (such as from leaching or weathering). Metals and other elements for which this soil half-life applies include arsenic, beryllium, cadmium, chromium (VI), lead and mercury.

Hexavalent chromium (CrVI) undergoes reduction to a less toxic species (CrIII). Characterizing the reduction of chromium (VI) to chromium (III), however, is complex and "it is not possible to predict how chromium compounds will behave in soil until the soil environment has been adequately characterized" (Cohen et al., 1994, citing Gochfeld and Whitmer, 1991). Several tests have been suggested for evaluating the reducing capacity of soils and may be considered in the development of site-specific information (Cohen et al., 1994, citing Bartlett and James, 1988; Walkley and Black, 1934). These tests are described as follows:

> "(1) Total Cr(VI) Reducing Capacity. Use the Walkley-Black (1934) soil organic matter determination in which carbon oxidizable by $K_2Cr_2O_7$ is measured by titrating the Cr(VI) not reduced by a soil sample (in suspension with concentrated H_2SO_4) with $Fe(NH_4)_2(SO_4)_2$.
>
> (2) Available Reducing Capacity. Shake 2.5 cm^3 of moist soil 18 hours with 25 mL of 0.1 to 10mM chromium as $K_2Cr_2O_7$ in 10mM H_3PO_4, filter or centrifuge, and determine Cr(VI) not reduced in the extract by the s-diphenylcarbazide method.
>
> (3) Reducing Intensity. The procedure is the same as that used in (2) above except that 10mM KH_2PO_4 should be used in the matrix solution in place of H_3PO_4."

G.2 Organics

G.2.1 Creosotes

Creosotes are of concern primarily because of the polycyclic aromatic hydrocarbon content. Therefore, in terms of soil half-life of this complex mixture, OEHHA recommends using the half-life for benzo(a)pyrene (see below).

G.2.2 Diethylhexylphthalate

Howard et al (1991) estimated a soil half-life base don the biodegradation rate of bis(2-ethylhexyl)phthalate. No measurements of soil half-life could be located. Based on the physical properties, this compound is expected to bind to soil tightly and to leach appreciably (Howard et al, 1991). Howard et al (1991) present both a low estimate and a high estimate. OEHHA recommends the average of the low and high estimates for soil half-life, 23 days, based on aqueous aerobic biodegradation measurements.

G.2.3 Hexachlorobenzene

A soil half-life estimate for hexachlorobenzene was made based upon sampling of unacclimated aerobic soil (Beck and Hansen, 1974; Howard et al., 1991). Results showed a soil half-life of 969-2089 days. The arithmetic mean of the limits of the range (1529 days) is recommended as the default half-life value for hexachlorobenzene.

G.2.4 Hexachlorocyclohexanes

Howard et al present high and low estimates for each hexachlorocyclohexane (alpha, beta, delta, and gamma). The low estimates are all 13.8 days and are based on hydrolysis half-life as measured by Ellington et al (1987). The high estimates range from 100 to 135 days and are based on aerobic soil die-away studies of Macrae et al (1984). OEHHA recommends using the average of the high and low estimates, 67 days, as the soil half-life for hexachlorocyclohexanes.

G.2.5 4,4'-Methylenedianiline

Howard et al present low (1 day) and high (7 days) estimates of the soil half-life for 4,4'-methylenedianiline based upon unacclimated aqueous aerobic biodegradation half-life. OEHHA recommends using the average of the two estimates, 4 days, as the soil half-life.

G.2.6 Pentachlorophenol

Estimates of soil half-life for pentachlorophenol in an aerobic unacclimated environment were reported to range from 23 to 178 days (Howard et al., 1991). Increased content of organic matter in the soil has also been reported to increase the half-life of pentachlorophenol in soil by decreasing the bioavailability of the compound (ATSDR, 1994). Flooded soils and paddy soils have half-lives on the order of 10 to 120 days (ATSDR, 1994; Ide et al., 1972; Kuwatsuka and Igarashi, 1975). The arithmetic mean of the limits of the range (100 days) is recommended as the default half-life for pentachlorophenol.

G.2.7 Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls are a mixture of chlorinated biphenyls. As such an overall soil half-life for PCBs is difficult to ascertain. A half life of 940 days for Aroclor 1254 was derived by Hsieh et al. (1994). This value is used by the Department of Toxic Substances Control in CalTOX. OEHHA proposes to use this value for all Aroclors.

G.2.8 Polycyclic Aromatic Hydrocarbons (PAHs)

There are a variety of polycyclic aromatic hydrocarbons emitted from combustion sources. The structures vary by number and placement of benzene rings and functional groups on those rings. The prototype PAH from a toxicological perspective is benzo(a)pyrene. However, it may not be the best prototype when it comes to soil half-life. The average of low and high estimates of soil half-lives presented in Howard et al (1991) for various PAHs ranges from 24 to 1524 days. These are based largely on the studies of Coover and Sims (1987), Groenewegen and Stolp (1976), and Sims (1990). The average of all estimates is 570 days. Given that the PAHs are usually reported under the Air Toxics Hot Spots program as total PAHs and when speciated only usually include 6 or so specific PAHs, it seemed reasonable to use this average value for a soil half-life for PAHs. Therefore, OEHHA is recommending that the half-life for PAHs be set at 570 days.

G.2.9 Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (PCDD/F)

The compound of primary concern in the dioxin and furan family of compounds is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Sampling of 32 sites in Seveso, Italy, produced an initial calculated regression half-life of one year (365 days) (Di Domenico et al., 1980). Experimental application of TCDD to two different soil types (loamy sand and silty clay loam) for 350 days produced calculated half-life values ranging from 394 to 708 days (Kearney et al., 1972; Kearney et al., 1973). Soil half-life estimates ranging from 10 to 12 years (3650-4380 days) were reported based upon experimental measured soil concentrations of TCDD from a contaminated site at an Air Force base in Florida (Young, 1981). Soil half-life estimates of 10 to 100 years (3650-36500 days) were reported, depending on the depth of the contamination, with deeper soil having reduced biodegradation rates (Nauman and Schaum, 1987). An estimated soil half-life of 3609 days has also been reported (calculated from a soil reaction rate constant of 8×10^{-6} hr^{-1}) (Mackay et al., 1985).

Several other half-life estimates have also been identified and summarized (Cohen et al., 1994). Soil samples showing loss of TCDD content by volatilization produced estimated half-lives of 7-24 days (Nash and Beall, 1980). TCDD measure in soils from the contaminated site in Seveso, Italy, produced a half-life estimate of 9.1 years (3322 days) (Cerlesi et al., 1989). A half-life estimate of 3 days was made based on loss of TCDD content from soil by both photodecomposition and volatilization (Di Domenico et al., 1982).

The arithmetic mean of the twelve reported values (4720 days) is recommended as the estimated soil half-life of TCDD (Hsieh et al, 1994).

TableG-1. Soil Half-life Values (Days).

Compound	Soil Half-life (days)
Arsenic	1.0 E+08
Beryllium	1.0 E+08
Cadmium	1.0 E+08
Chromium	1.0 E+08
Creosotes	5.7 E+02
Diethylhexylphthalate	2.3 E+01
Hexachlorobenzene	1.53 E+03
Hexachlorocyclohexanes	6.7 E+01
Lead	1.0 E+08
Mercury	1.0 E+08
4,4’-methylenedianiline	4.0 E+00
PAHs	5.7 E+02
PCBs	9.4 E+02
PCDD/F	4.72 E+03
Pentachlorophenol	1.0 E+02

G.3 References

ATSDR (1990). Agency for Toxic Substances and Disease Registry. US Public Health Service toxicological profile for 2,4,6-trichlorophenol.

ATSDR (1994). Agency for Toxic Substances and Disease Registry. US Public Health Service toxicological profile for pentachlorophenol.

Bartlett, R.J. and James, B.R. (1988). Mobility and bioavailability of chromium in soils. In: Chromium in the Natural and Human Environments. Nriagu, J.O. and Nierboor, E. (eds). John Wiley and Sons, New York, pp.267-383.

Beck, J. and Hansen, K.E. (1974). The degradation of quintozene, pentachlorobenzene, hexachlorobenzene, and pentachloroaniline in soil. Pesticide Science, 5:41-8.

Cerlesi, S., Domenico, A., and Ratti, S. (1989). 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) persistence in the Seveso (Milan, Italy) soil. Ecotoxicol Environ Safety, 18:149-64.

Cohen, Y., Winer, A.M., and Creelman, L. (1994). Development of intermedia transfer factors for hexavalent chromium. Final report prepared for the Air Resources Board in fulfillment of contract number A032-170.

Cohen, Y., Winer, A.M., and Pesinova, V. (1994). Development of intermedia transfer factors for 2,3,7,8-TCDD. Final report prepared for the Air Resources Board in fulfillment of contract number A032-170.

Coover, M.P. and Sims, R.C.C. (1987). The effects of temperature on polycyclic aromatic hydrocarbon persistence in an unacclimated agricultural soil. Hazardous Waste and Hazardous Materials, 4:69-82.

Di Domenico, A., Silano, V., Viviano, G., and Zapponi, G. (1980). Accidental release of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) at Seveso, Italy. V. Environmental persistence of TCDD in soil. Ecotoxicol Environ Safety, 4:339-45.

Di Domenico, A., Viviano, G., and Zapponi, G. (1982). Environmental persistence of 2,3,7,8-TCDD at Seveso. In: Chlorinated Dioxins and Related Compounds: Impact on the Environment. pp.105-14.

Ellington, JJ, FE Stancil, WD Payne, CD Trusty. (1988). Measurements of hydrolysis rate constants for evaluation of hazardous waste land disposal:Vol 3. Data on 70 chemicals. EPA-600/3-88-028. NTIS PB88-234-042/AS.

Gochfeld, M. and Whitmer, C. (1991). A research agenda for environmental health aspects of chromium. Environ Health Perspect, 92:141-4.

Groenewegen, D. and Stolp, H. (1976). Microbial breakdown of polycyclic aromatic hydrocarbons. Zentralbl Bakteriol [Orig B], 162:225-32.

Haider, K., Jagnow, G., Kohnen, R., and Lim, S.U. (1974). Degradation of chlorinated benzenes, phenols, and cyclohexane derivatives by benzene and phenol utilizing soil bacteria under aerobic conditions. Arch Microbiol, 96:183-200.

Herbes, S.E. and Schwall, L.R. (1978). Microbial transformation of polycyclic aromatic hydrocarbons in pristine and petroleum contaminated sediments. Appl Environ Microbiol, 35:306-16.

Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M., and Michalenko, E.M. (1991). Handbook of Environmental Degradation Rates. Printup, H.T. (ed). Lewis Publishers, Chelsea, MI.

Hsieh, D.P.H., McKone, T.E., Chiao, F., Currie, R.C., and Kleinschmidt, L. (1994). Final Draft Report: Intermedia transfer factors for contaminants found at hazardous waste sites. Prepared for the Office of Scientific Affairs, Department of Toxic Substances Control, California Environmental Protection Agency. November, 1994.

Ide, A., Niki, Y., Watanabe, I. *et al.* (1972). Decomposition of pentachlorophenol in paddy soil. Agric Biol Chem, 36:1937-44.

Inman, JC, SD Strachan, LE Sommers, DW Nelson. (1984). The decomposition of phthalate esters in soil. J. Environ. Sci. Health. B19:245-57.

Johnson BT, W Lulves. (1975) Biodegradation of di-n-butylphthalate and di-e-ethylhexyl phthalate in freshwater hydrosoil. J. Fish. Res. Board Can. 32:333-9.

Kearney, P.C., Woolson, E.A., and Ellington, C.P. (1972). Persistence and metabolism of chlorodioxins in solids. Environ Sci Technol, 5:273-7.

Kearney, P.C., Woolson, E.A., Isensee, A.R., and Helling, C.S. (1973). Tetrachlorodibenzodioxin in the environment: sources, fate, and decontamination. Environ Health Perspect, 5:273-7.

Kincannon, D.F. and Lin, Y.S. (1985). Microbial degradation of hazardous wastes by land treatment. Proceedings of the Industrial Waste Conference, 40:607-19.

Kuwatsuka, S. and Igarashi, M. (1975). Degradation of PCP in soil: II. the relationship between the degradation. Soil Sci Plant Nutr, 21:405-14.

Mackay, D., Paterson, S., Cheung, B., and Neely, W.B. (1985). Evaluating the environmental behavior of chemicals with a level III fugacity model. Chemosphere, 14:335-74.

Macrae IC, Y Yamaya, T Yoshida. (1984) Persistence of hexachlorocyclohexane isomers in soil suspensions. Soil Biol. Biochem. 16:285-6.

Nash, R.G. and Beall, M.L. (1980). Distribution of silver, 2,4-D and TCDD applied to turf in chambers and field pots. J Agric Food Chemistry, 28:614-23.

Nauman, C.H. and Schaum, J.L. (1987). Human exposure estimation for 2,3,7,8-TCDD. Chemosphere, 16:1851-6.

Schouten MJ, JWC Peereboom, UAT Brinkman.(1983). Liquid chromatographic analysis of phthalate esters in Dutch river water. Int. J. Analyt. Chem. 7:13-23.

Sims, RC. (1990). Fate of PAH compounds in soil:loss mechanisms. Environ. Tox. Chem. 9: .

Shanker, R, C Ramakrishna, PK Seth. (1985). Degradation of some phthalic acid esters in soil. Environ. Pollut. Ser. A. 39:1-7.

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37:29-38.

Young, A.L. (1981). Long-term studies on the persistence and movement of TCDD in a natural ecosystem. In: Human and Environmental Risks of Chlorinated Dioxins and Related Compounds. Tucker, R.E., Young, A.L., and Gray, A.P. (eds). Plenum, New York.