THE EFFECT OF CO-POLLUTANT DEGRADATION ON PARTITIONING OF POLYCHLORINATED DIOXINS IN SATURATED SOILS

S. Kapila, R.K. Puri, A.F. Yanders, Silvia Cerlesi*, and A.A. Elseewi**

Environmental Trace Substances Research Center, Columbia, Missouri 65203; *Regione Lombardia, Milan, Italy; and **Southern California Edison, Rosemead, California 91770

ABSTRACT

The effect of co-pollutant degradation on partitioning of polychlorinated dioxins in saturated soils under aerobic and anaerobic conditions was investigated. The results obtained indicate that the degradation of co-pollutants such as pentachlorophenol, naphthalene and methylnaphthalene is highest under aerobic conditions. The concentration of "free" PCDDs in the aqueous phase decreased with the decrease in the concentration of co-pollutants.

INTRODUCTION

Certain wood treatment operations conducted over the past 40 years without environmental precautions have led to extensive contamination of soil and groundwater at many sites in the United States. Particular concern has resulted from the detection of highly toxic polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in soil and water. These compounds are highly persistent in the soil environment (1-5). Due to their high toxicity, the presence of these compounds, even at ultra-trace levels (European Standard 50 ppq), has been deemed unacceptable in groundwaters. The physicochemical properties of these compounds suggest that their downward movement should be negligible, and this is supported by leaching studies conducted with pure compounds (6,7). The measurable contamination of aquifers observed at wood treatment sites is related to the presence of co-contaminants, mainly the light petroleum components of pentachlorophenol treatment formulations (8,9). The groundwater contamination is in the form of a colloidal suspension and is dependent on the persistence of co-contaminants in the saturated soil environment. The present study was initiated to monitor the effect of co-pollutant degradation on the partitioning of polychlorinated dioxins in saturated soils under aerobic and anaerobic conditions. In addition, the effects of a denitrification process on the degradation of co-pollutants and PCDD sorption behavior were also monitored.

EXPERIMENTAL

Aliquots of soils were obtained from Times Beach, Missouri, and from a wood treatment site in southern California. The soils were air dried and sieved to remove the particles larger than 2 mm. The sieved soils were divided into two portions, one of which was sterilized in an autoclave. The sterilized and

non-sterilized soils were then spiked with a mixture of PCDDs with 3 to 8 chlorine substitutions and a mixture of 5% pentachlorophenol and petroleum oil. The spiked soils were transferred to shake flasks. Deaerated water was added to one set of shake flasks containing non-sterilized soil. Aerated water was added to another set of flasks containing sterilized and non-sterilized soils. Potassium nitrate was added to a set of non-sterilized soil with deaerated water. The flasks were allowed to equilibrate for periods ranging up to 180 days. Aliquots of water and soil were taken at six different time intervals. The concentrations of oil components, pentachlorophenols and PCDDs were determined. Experiments were carried out in duplicate with three different levels of the contaminant concentrations.

RESULTS AND DISCUSSION

The objective of the present study was to monitor the degradation of co-pollutants commonly associated with PCDDs at wood treatment facilities and its effect on binding of PCDDs in a saturated soil environment. The results obtained so far indicate that the degradation of co-pollutants such as pentachlorophenol, naphthalene and methylnaphthalene is highest under aerobic conditions. Under these conditions, the concentration of the naphthalene dropped from 2500 ppm to less than 1 ppm in 180 days. Similar results were obtained for pentachlorophenol, in which case the concentration dropped from 5000 ppm to less than 1 ppm over the same period. These decay curves follow typical first order rate kinetics. The decay is much faster at higher concentrations. The half-life at lower concentrations is much longer. These results are in agreement with the results reported in the literature (10-13). As expected, little or no degradation was observed in the sterilized system. The concentration of "free" PCDDs, i.e., the concentration in the aqueous phase, decreased with the decrease in the concentration of co-pollutants. It should be pointed out that almost all of the so-called free concentration is associated with the colloidal suspension of co-pollutants. In the absence of colloidal suspensions, the higher concentration of co-pollutants actually results in an increased binding of PCDDs to the soil matrix. The long term stability of co-pollutants is related to the very low level of microbial activity in the predominantly anaerobic conditions which exist in deep aquifers. Enhanced degradation of polynuclear aromatics has been shown to occur under denitrification conditions (14,15). The effect of denitrification on the degradation of co-pollutants and its effect on the adsorption behavior of PCDD is also being examined.

REFERENCES

1. Kearney, P.C., E.A. Woolson and C.P. Ettington, Environmental Science and Technology 6(12), 1017-1019 (1972).

2. Matsumura, F. and S.H. Benzet, Environmental Health Perspectives 5, 253-258

3. Esposito, M.P., T.O. Tiernan, and F.E. Dryden, Dioxins, U.S.E.P.A., IERL, Office of Research and Development, Cincinnati, Ohio, EPA-600/2-80-197, pp. 230-246 (1980).

4. Kapila, S, A.F. Yanders, C.E. Orazio, S.F. Manahan, S. Cerlesi, and T.E. Clevenger, Chemosphere 18, 1296-1304 (1989).

5. Yanders, A.F., C.E. Orazio, R.K. Puri and S. Kapila, Chemosphere 18, 429 432 (1989).

6. Crummel, W.B. and R.H. Stehl, Environ. Health Perspectives 5, 15-25 (1973).

7. Walters, R.W., A. Guiseppi-Elie, M.M. Rao, and J.C. Means, in Chlorinated Dioxins and Dibenzofurans in Perspective, Rappe, C., Choudhary, G. and Keith, L.H., Eds., Lewis Publishers, Inc., Michigan (1986).

8. Puri, R.K., T.F. Clevenger, S. Kapila, A.F. Yanders and R.K. Malhotra, Chemosphere 18, 1291-1296 (1989).

9. Puri, R.K., S. Kapila, Yun-Hsieh Lo, A.F. Yanders and A.A. Elseewi, Accepted for publication, Chemosphere (1990).

10. Kaufman, D.D., in Pentachlorophenol, R.K. Rao, Ed., Plenum Press, New York (1978).

11. Kuwatsuka, S. and M. Igersahi, Soil Sci. Plant Nutri., 21(4), 405-414 (1975).

12. Bulman, R. and J.B. Weber, Report No. 85 1. Petroleum Inc. for Conservation of the Canadian Environment, Ottawa, Canada (1985).

13. Mihelcic, J.R. and R.G. Luthy, Applied and Environmental Microbiology 54, 1182-1187 (1988).

14. Aranha, H.G. and L.R. Brown, Applied and Environmental Microbiology 42, 74-78 (1981).

15. Mihelcic, J.R. and R.C. Luthy, Applied and Environmental Microbiology 54, 1183-1198 (1988).