Bull. Environ. Contam. Toxicol. (1985) 35:723–728

Bulletin of Environmental Contamination and Toxicology

Loss of The Herbicide Triallate from a Clay Soil Containing Aged and Freshly Applied Residues

Allan E. Smith and Leo J. Milward

Agriculture Canada, Research Station, Box 440, Regina,
Saskatchewan, S4P 3A2, Canada

When a pesticide residue remains in contact with field soils for prolonged periods a phenomenon known as aging, or weathering, can occur. Although the mechanisms involved during the aging process are poorly understood, it is generally considered that physical forces result in an increased adsorption of the chemicals to soil colloids (Adams 1973; Chiba 1969; Hamaker and Goring 1976; Saha et al. 1969). It has also been noted (Adams 1973; Khan 1973) that with time a diffusion of pesticide molecules into the interior of clay and humic colloids may occur. Such mechanisms can provide protection from microbial decomposition in the soil by reducing the concentration of the chemical in the soil solution; though this may not occur in every case (Hurle and Walker 1980).

Byast and Hance (1981) have measured the decomposition rates of aged residues of the herbicides linuron and simazine under laboratory conditions and compared these data with those from freshly applied residues. It was noted (Byast and Hance 1981) that aged residues of linuron disappeared more slowly from the soil than freshly applied chemical, whereas simazine underwent breakdown at similar rates whether the residues were aged or freshly added. These results were explained (Byast and Hance 1981) on the basis that the availability of linuron, but not simazine, could have been reduced in the case of the aged residues as a result of an increased adsorption of linuron to the soil.

The soil-applied herbicide triallate is extensively used on the Canadian prairies and in Saskatchewan, alone, over 20% of cropland sown to cereal and oilseed crops receive treatments with the chemical (Smith 1982). The herbicide is persistent and carry-over of residues from one crop year to the next occurs (Smith 1982). Triallate is also strongly adsorbed to soil organic matter (Grover et al. 1979) and has soil adsorption constants similar to those for linuron (Grover et al. 1979; Hance 1965, 1967).

In the experiments to be described, the rates of breakdown of triallate residues present in a clay field soil that had been treated with the herbicide 6 months and 12 months previously were compared to the dissipation rates in the same soil containing fresh herbicidal treatments, to determine whether the availability of the herbicide to microbial degradation is changed with aging of the residues in field soil.

MATERIALS AND METHODS

The field soil was a clay of the Regina Association, classified as a Dark Brown Chernozemic, Rego Dark Brown and had a composition of 69% clay, 26% silt and 5% sand. The organic carbon content was 4.2%, the soil pH was 7.7, and the wilting point and field capacity moisture levels were 20 and 40% respectively.

A commercial formulation of triallate was applied to the soil surface at a rate of 1.4 kg/ha during the second week of May, 1983, and harrowed in immediately to a depth of 5 cm. Four hours after application a second harrowing, at right angles to the first, completed soil incorporation. Part of the field was left untreated to allow collection of herbicide-free soil. Both treated and untreated areas were seeded with wheat (*Triticum aestivum* var. Neepawa).

After 6 months, 50 cores (7.5 cm in diameter) were randomly collected from the top 7.5 cm depths of the triallate-treated field soil and pooled. Immediately after collection, the soil was poured 20 times through a Riffle sampler to thoroughly mix the soil and evenly distribute the remaining triallate. A similar number of soil cores were collected from the herbicide-free areas of the field and, after mixing as described, used for control purposes. Replicate samples (4 x 50 g) of the treated and untreated soils were analyzed (see later) for triallate content. The former contained 0.53 ± 0.03 µg/g and the latter <0.01 µg/g.

Samples (50 g) of the triallate-containing field soils were weighed into 175-mL capacity foam cartons and moistened to 85% of field capacity. The cartons were loosely capped, to reduce moisture evaporation but allow air exchange, and incubated in the dark at 20 ± 1°C. For comparative purposes, samples (50 g) of the herbicide-free soil were treated with a solution of triallate (26.5 µL; 1.00 mg triallate/mL methanol) so that the herbicide concentration in the control soils was the same as in the soils containing the aged residues. After thorough stirring to evenly distribute the herbicide throughout the soil, distilled water was added to moisten the control soils to 85% of field capacity, the cartons were loosely capped, and placed in the dark in the incubator with the cartons containing the samples of aged residues. Distilled water was added to all cartons (by weight) every second day to maintain moisture levels. Duplicate samples from both treatments were extracted and analyzed for triallate remaining after 1 hour and then after 7, 14, 28, 42, 63 and 84 days.

After 12 months, treated and control soils were again collected and thoroughly mixed as described. The triallate content of the treated field soil (based on 4 x 50 g samples) was 0.40 ± 0.02 µg/g. Thus, control soil samples (50 g) were treated with 20 µL of the triallate solution to give the same concentration as for the aged residues. As before, soils (50 g) containing the aged and freshly applied triallate were moistened to 85% of field capacity and incubated together at 20 ± 1°C. Duplicate samples were extracted and analyzed for herbicide remaining after 1 hour and then after 7, 14, 28, 42, 63 and 84 days.

At every sampling time, the soil from each carton was extracted with 20% aqueous acetonitrile containing 2.5% of glacial acetic acid using an overnight extraction procedure. Triallate was partitioned into hexane and quantified gas chromatographically. Full details of the extraction and analysis have been described (Smith and Milward 1983).

RESULTS AND DISCUSSION

When pesticide residues are aged and become more strongly adsorbed onto soil colloids they also become more resistent to solvent extraction (Chiba 1969; Saha et al. 1969; Smith 1978, 1981; Smith and Milward 1983), so that choice of extraction procedure for the recovery of aged triallate residues from the field soils was important. A previous study has indicated (Smith and Milward 1983) that aqueous acetonitrile containing a small amount of glacial acetic acid, in combination with an overnight extraction procedure, consistently recovered more aged triallate residues from a variety of soils treated one year previously with the chemical than did several other solvent systems and extraction processes. Thus, this method was adopted for the present study to ensure efficient recoveries.

It has been demonstrated that triallate can be lost from treated soils by both biological processes (Banting 1967; Smith 1969) and by volatilization (Banting 1967; Beestman and Deming 1976; Grover et al. 1981; Jury et al. 1980). However, in the present studies, biological losses were assumed to predominate since the research of Jury et al. (1980) has shown that over a 30-day period volatility losses of triallate from the surface of moist soils, into which the herbicide had been incorporated, were less than 5% of that applied. It was also noted (Jury et al. 1980), that because triallate is so strongly absorbed to soil, upward movement of the herbicide to the soil surface did not occur; consequently, volatility losses of triallate from the soil surface rapidly decreased with time. In the present study the soils remained undisturbed and water added to maintain the moisture levels was allowed to distribute itself by percolation and diffusion.

To preclude any effects resulting from adaption of soil microflora to degrade the herbicide, the field soils had received no previous treatments with triallate. Prior to incubation, control soils were treated at the same rates as those remaining in the treated field soils to obviate any herbicide concentration effects that might affect the rates of degradation.

The results of the biological degradation of aged and freshly applied residues of triallate under laboratory conditions in the

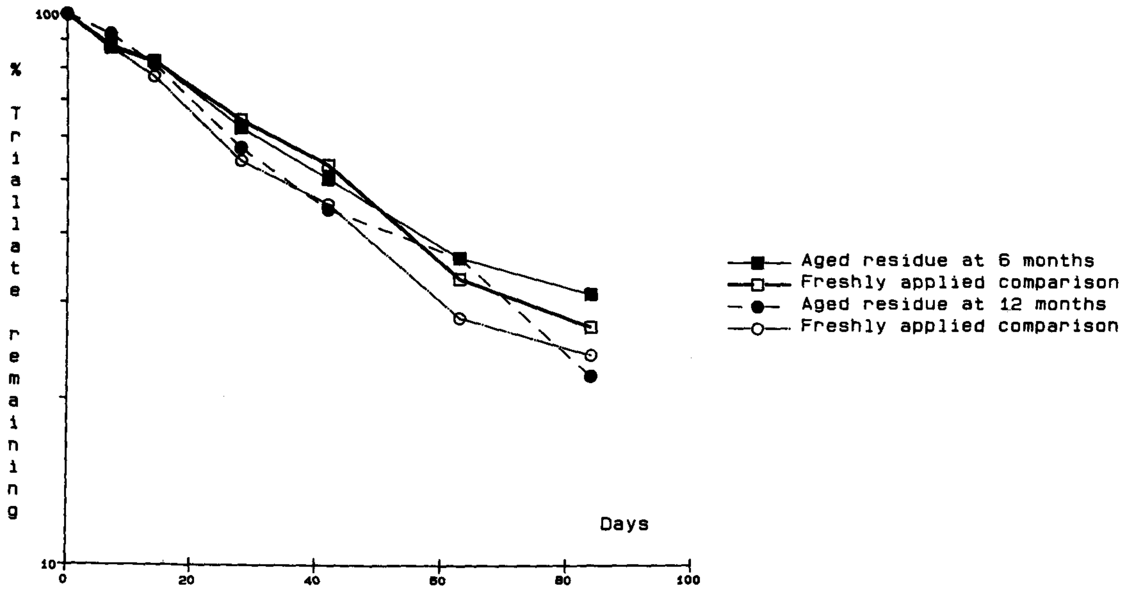

Fig.1 Loss of aged and fresh triallate from heavy clay

clay at 20 ± 1°C and 85% of field capacity moisture are summarzied in Fig. 1. All degradation data followed first-order kinetics and in all cases the regression mean square was greater than 0.98 (Table 1). The linear regression equations for the degradation of triallate, together with the half-life values ($T_{\frac{1}{2}}$) for the herbicide in the soils, are compared in Table 1. From the results (Fig. 1; Table 1) it can be calculated that at each sampling date there was no significant difference in the breakdown rates of aged and freshly applied triallate in soil. There was a slight difference (significant at P = 0.05) between breakdown rates of triallate in soils collected after 12 months compared to those sampled at 6 months. This difference could be attributed to a slightly greater population of microbial degrading organisms in the soil in the spring of 1984 than was present during the fall of 1983.

Table 1. Equations and half-life values for the degradation of aged and freshly applied residues of triallate in a clay soil.

Treatment	Log(% triallate) at T days	RMS*	$T_{\frac{1}{2}}$**
Aged 6 months	1.99 - 0.00633T	0.99	45
Fresh comparison	2.00 - 0.00700T	0.99	43
Aged 12 months	2.00 - 0.00774T	0.99	39
Fresh comparison	1.98 - 0.00773T	0.98	37

* Regression mean square. **Half-life in days.

From these studies it would appear that triallate is similar to simazine rather than linuron (Byast and Hance 1981) in that aged residues degrade in the soil at a similar rate to that of freshly applied herbicide. This suggests that soil adsorption does not significantly reduce the availability of triallate to microbial degradation.

REFERENCES

Adams RS (1973) Factors influencing soil adsorption and bioactivity of pesticides, Res Rev 47:1-54

Banting JD (1967) Factors affecting the activity of di-allate and tri-allate. Weed Res 7:302-315

Beestman GB, Deming JM (1976) Triallate mobility in soils. Weed Sci 24:541-544

Byast TH, Hance RJ (1981) Decomposition of linuron and simazine incubated with soil containing aged residues. Proc. EWRS Symp: Theory and Practice of the Use of Soil Applied Herbicides, pp 56-62

Chiba M (1969) Factors affecting the extraction of organochlorine insecticides from soil. Res Rev 30:63-113

Grover R, Banting JD, Morse PM (1979) Adsorption and bioactivity of di-allate, tri-allate and trifluralin. Weed Res 19:363-369

Grover R, Kerr LA, Khan SU (1981) Multidetector gas chromatographic determination and confirmation of airborne triallate residues in Saskatchewan. J Agric Fd Chem 29:1082-1084

Hamaker JW, Goring CAI (1976) Turnover of pesticide residues in soil. In: Kaufman DD, Still GG, Paulson GD, Bandal SK (eds) Bound and conjugated pesticide residues. ACS Symposium Series 29, pp 219-243

Hance RJ (1965) The adsorption of urea and some of its derivatives by a variety of soils. Weed Res 5:98-107

Hance RJ (1967) The speed of attainment of sorption equilibria in some systems involving herbicides. Weed Res 7:29-36

Hurle K, Walker A (1980) Persistence and its prediction. In: Hance RJ (ed) Interactions between herbicides and the soil. Academic Press, London, pp 83-122

Jury WA, Grover R, Spencer WF, Farmer WJ (1980) Modeling vapor losses of soil-incorporated triallate. Soil Sci Soc Amer J 44:445-450

Khan SU (1973) Equilibrium and kinetic studies of the adsorption of 2,4-D and picloram on humic acid. Can J Soil Sci 53:429-434

Saha JG, Bhavaraju, B, Lee YW (1969) Validity of using soil fortification with dieldrin to measure solvent extraction efficiency. J Agric Fd Chem 17:874-876

Smith AE (1969) Factors affecting the loss of tri-allate from soils. Weed Res 9:306-313

Smith AE (1978) Comparison of solvent systems for extracting herbicide residues from weathered field soils. Pestic Sci 9:7-11

Smith AE (1981) Comparison of solvent systems for the extraction of atrazine, benzoylprop, flamprop, and trifluralin from weathered field soils. J Agric Fd Chem 29:111-115

Smith AE (1982) Herbicides and the soil environment in Canada. Can J Soil Sci 62:433-460

Smith AE, Milward LJ (1983) Comparison of solvent systems for the extraction of diclofop acid, picloram, simazine, and triallate from weathered field soils. J Agric Fd Chem 31:633-637

Received September 24, 1984; accepted January 10, 1985.