

Some Factors Causing Variability in 1,2-Dibromo-3-Chloropropane Concentrations in Soil

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Abstract: Relative to nematicides with greater fuming capabilities, 1,2-dibromo-3-chloropropane (DBCP) moved nonuniformly through soil. DBCP concentrations in soil were reduced by low soil temperature and the presence of lime or roots within the soil profile. Applications by either water or chisel injection provided DBCP movement to 120 cm and below. Concentrations were least persistent in the upper 15 cm of the field surface and in one situation where application was not followed by irrigation. Values for Henry's Constant are reported for DBCP at a range of solution temperatures. Certain advantages and disadvantages of soil atmosphere sampling of DBCP are discussed. *Key Words:* degradation, soil temperature, sorption.

Several researchers have quantified the movement, concentrations, and persistence of 1,2-dibromo-3-chloropropane (DBCP) in soil (2, 3, 4, 12). Their analytical techniques (5) involved the timed removal of soil at various depths and distances from the site of DBCP application. This step was followed by DBCP extraction and chromatographic determination of the DBCP concentrations present. All previous data have been obtained essentially from soils devoid of living plant roots. In most cases the researchers provided extensive characterization of the field conditions under which their work was done.

Our interest in DBCP began in 1974 when yield and nematode control from DBCP in established perennials proved highly variable. We believed that it might be advantageous and perhaps simpler to analyze repeatedly for DBCP in the soil atmosphere *in situ* (8) rather than from a soil extraction. When developing analytical techniques for soil atmosphere sampling, we worked in field situations similar to those described by Hodges and Lear (2). Under these conditions we observed the relative significance of several factors which influence DBCP movement and concentrations in soil. A comparison of our data with previous data brought some new implications to the fore.

MATERIALS AND METHODS

Determination of Henry's Constant. Low concentrations of emulsified DBCP, ranging from 4 to 40 $\mu\text{g}/\text{ml}$, were placed in 950-ml Mason jars containing 475 ml of tap

water. The solution was well mixed and jars were stored in constant-temperature incubators at a range of temperatures between 5 and 26 ± 1 C. There were five replicates at each temperature. After 48 h, the lids were punctured and quickly resealed with a small rubber serum stopper. At this time a syringe needle was inserted through the stopper and a gas sample was removed and analyzed for DBCP concentration. From these data a curve was drawn for the Henry's Constant value (K_h) of DBCP. The higher the numerical value the greater the chemical's affinity for solubilization compared to vaporization.

Field experiments. During 1975 and 1976, DBCP was applied by several methods to a field of relatively uniform texture located at the Kearney Horticulture Field Station in Parlier, California. The soil was a Hanford Sandy Loam containing 61% sand, 31% silt, 8% clay. Moisture content was determined by oven-drying soil samples at 105 C for 24 h. The permanent wilting percentage was 4.0%. Carbon content, as determined by dry combustion, did not exceed 1% except where roots were present as a variable in the treatment. This deep soil is characterized as having a relatively low water permeability of 5 cm/24 h. No crops had been grown for 5 years (maintained fallow). Tillage occurred only in the surface 15 cm of the experiments.

DBCP used in all these experiments was from Fumazone 86 EC containing 1.45 kg ai/L (12.1 lb ai/gallon) and treatments were applied at 81 kg/ha rate of DBCP. Each experimental plot involved a treated area of about 25 m².

DBCP was applied in a manner similar to commercial methods. Tractor-drawn chisels were spaced 30 cm apart and placed

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7.5 to 10 cm beneath the field surface with a dragchain following each chisel. Basins were constructed so that the quantity of water supplied to each plot could be regulated. Following DBCP applications, the concentrations present in the soil atmosphere were monitored at various depths and times in order to develop an overall picture of DBCP concentrations, movement, and persistence.

Small-diameter stainless-steel tubing probes were introduced into field soils (7) for subsequent removal of soil atmosphere at various depths (8). Three such probes, with openings at depths of 7, 15, 30, 60, 90, and 120 cm were placed randomly in each treatment site.

Following DBCP application, soil air spaces were periodically sampled by extraction with a 30-cc glass syringe lubricated with a water film. Soil atmosphere drawn into the syringe was contained for 1 minute and discarded; then the tube was resampled. Following the third such sampling, the needle tip was sealed with polyurethane. Samples were stored no longer than 1 hour at field temperature. Accuracy of field sampling from repeated samples was within 15% error limits. Concentrations present in the soil water were calculated on the basis of Henry's Constant values established herein. Thus, the data presented are based on the concentration detected in the soil atmosphere.

Applications were made at slightly different soil temperatures and moisture levels, which are reported for each experiment. Treatments were sampled twice in the first week and irregularly thereafter.

In one set of experiments three adjacent sites were prepared and treated in August 1975. In site 1 the DBCP was mixed into water and applied as a 2.5-cm drench. After 8 h, 7.5 cm of water was applied. DBCP was applied by chisel at sites 2 and 3. Site 2 received a 10-cm water drench after 25 h. Site 3 was never irrigated.

A second set of experiments, conducted in the same plots in October 1976, tested three different methods of field preparation. Site 4 remained undisturbed except for tillage in the surface 5 cm. Site 5 was planted to grass, *Sorghum vulgare* var. Sudanese, 7 weeks before DBCP application. Aboveground portions were mowed closely,

and Sudan shoots were removed on the day of DBCP treatment. Roots were present 180 cm deep at the time of treatment. Site 6 received an incorporation of lime at 5.4 metric tons/ha within the upper 10 cm of field surface on the day before DBCP application. All 1976 applications were in 7.5 cm water. There was an additional 1.5 cm of rainfall 2 days after application. Soil moisture levels were similar in the three plots at the time of application.

RESULTS

Henry's Constant values. Fig. 1 shows the Henry's Constant values for low concentrations of emulsified DBCP. The values obtained were slightly greater than the expected value of 165 (1), and reduced temperatures greatly increased the values obtained.

Field experiments. Although each of the six treatment sites received the same quantity of DBCP, its movement and concentrations varied at specific soil depths and sampling times (Fig. 2). The concentrations were highest and most persistent at sites 1, 2, and 4. Nematotoxic concentrations (9) were marginal below the 90-cm depth. Persistence was least at site 3. After lime was applied at site 6, the soil pH at 15 cm increased from

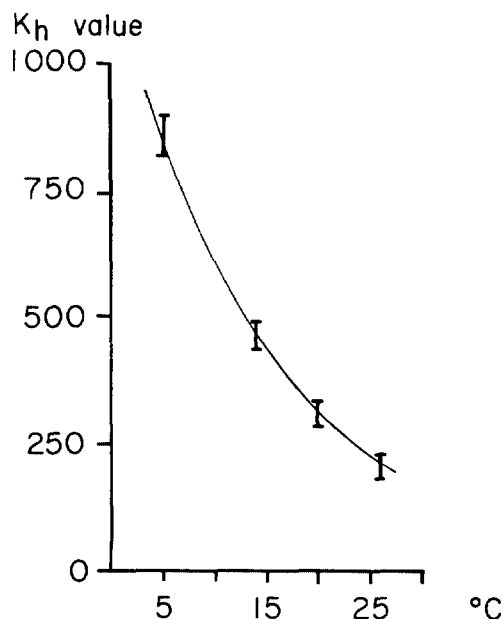


FIG. 1. The Henry's Constant (K_h) values of DBCP from Fumazone 86 EC at various solution temperatures.

Fig 2

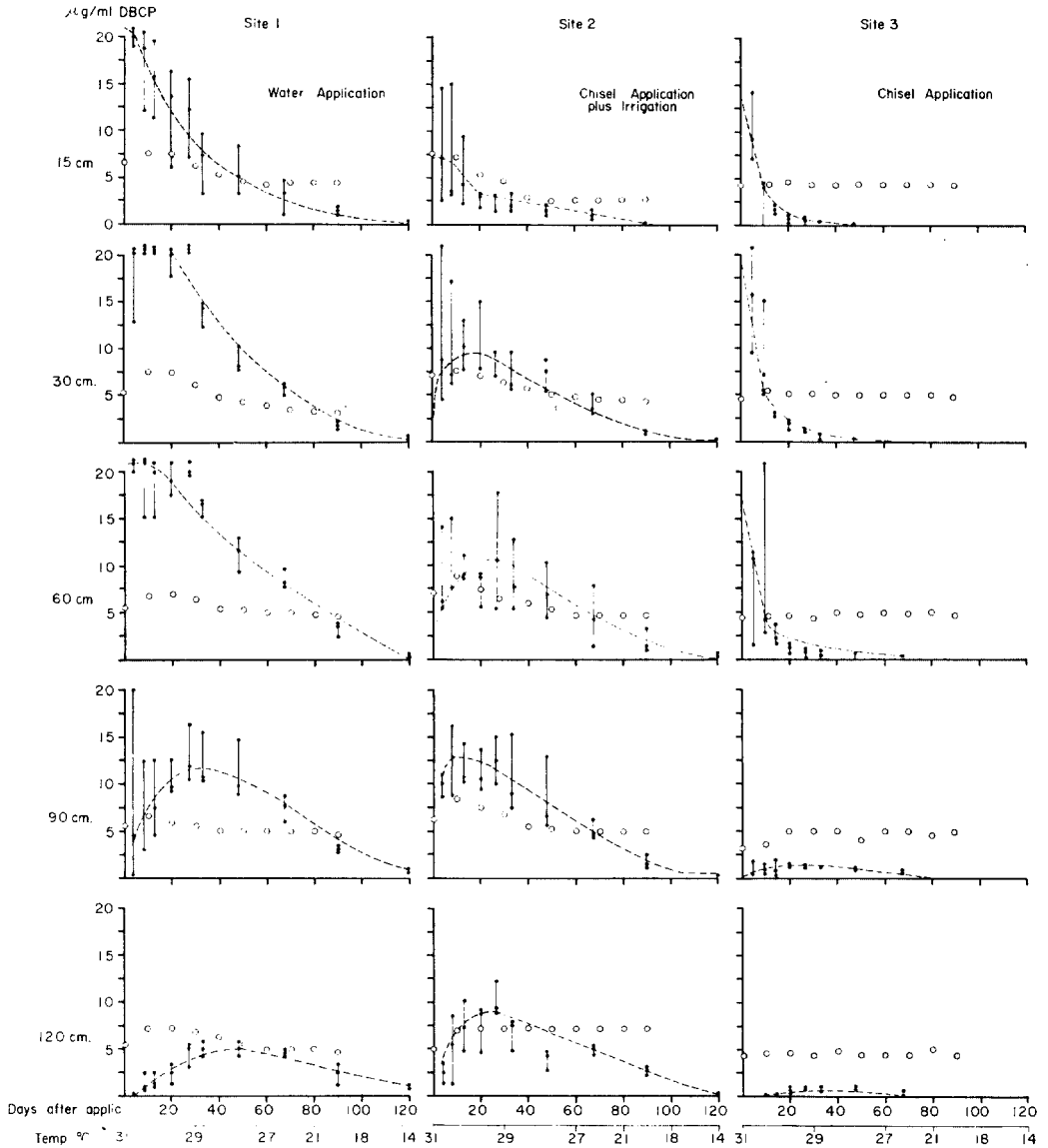


FIG. 2. Concentrations of DBCP in the soil solution following three application methods to three adjacent sites. The dots in each time frame depict the variability among the three sampling probes within each site. Site 1 received a water application. Sites 2 and 3 received chisel applications, but site 3 was not subsequently irrigated. Soil moisture percentages are indicated by circles.

7.2 to 11.2 and DBCP persistence was noticeably reduced at the soil surface.

Variability in DBCP concentrations was common among the three different sampling probes in each treatment site, whether the treatment involved chisel or water applications. Variability was least in warmer soils, most notably at sites 1 and 3. By the third day, chromatography of site 6 indicated the

presence of an unidentified chemical, presumably a DBCP degradation product, which quickly achieved high concentrations throughout the soil profile. It was most concentrated at the surface of the soil, disappeared within one month and was least persistent at lower depths. DBCP concentrations at sites 5 and 6 were low, but persistence was lengthy especially where

Fig 3

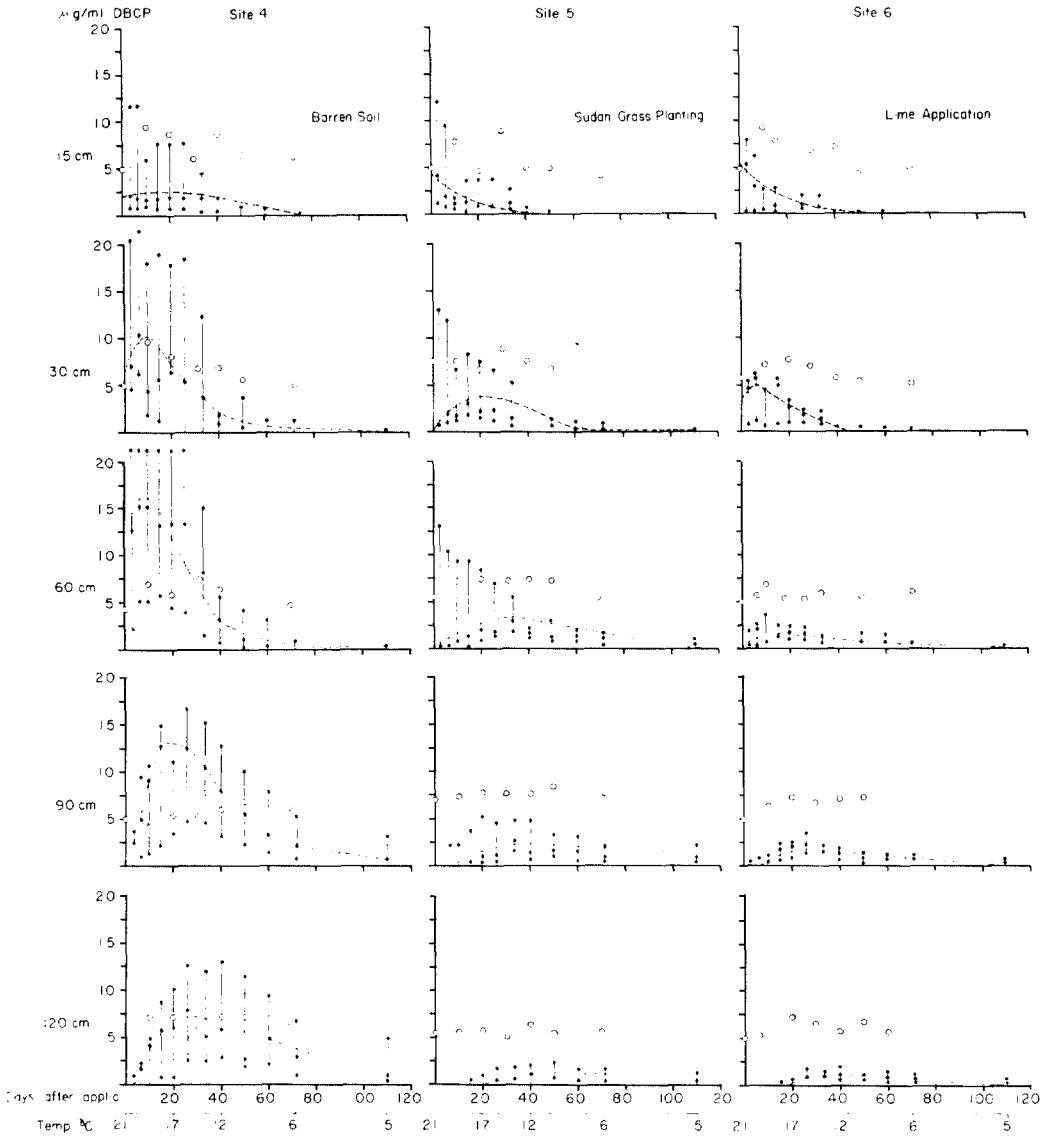


FIG. 3. Concentrations of DBCP in the soil solution following water applications at three adjacent sites with differing field conditions. The vertical bars depict the variability among 3 sampling probes within each site. Site 4 involved treatment of barren soil. Site 5 supported a 7-week-old Sudan grass planting, and site 6 had recently received a surface application of lime. Soil moisture percentages are indicated by circles.

roots were present. Treatments 4, 5, and 6 received an additional 8 cm of rainfall 40 days after application.

DISCUSSION

DBCP dispersal through a soil profile is irregular in comparison with other more volatile soil fumigants (7). Because chisels were spaced 30 cm apart, we anticipated

greatest variability in DBCP concentrations after application by chisel injection. Surprisingly, variability was equally apparent in sampling sites where drenches were the method of DBCP application. In our six test sites, and in those of Hodges and Lear (2), the eventual soil concentrations of DBCP were not greatly influenced by application method if the DBCP application was accompanied by irrigation. In practical field

situations it is apparent that the method of application can determine eventual success (10, 11).

Soil conditions influence the concentrations of DBCP moving through the soil profile. As with other alkyl halide soil fumigants, the concentrations were increased as soil temperature was increased. At 30 cm and deeper the lime application, perhaps through hydrolysis, resulted in lower DBCP concentrations, although DBCP persistence below 30 cm was maintained. The presence of roots also reduced DBCP concentrations, presumably as a result of increased absorptive sites. DBCP persistence was not impaired by the presence of roots. Where irrigation was not used, DBCP persistence was reduced.

The application rates tested were slightly higher than the rates used most commonly for established perennials. With lower rates, DBCP movement would probably be more restricted (4), although the concentrations would probably be similar to those reported here. It is most interesting that the absorptive capabilities of DBCP may be a significant factor enabling its use adjacent to living plants.

There is an inherent variability associated with the sampling of soil atmospheres for DBCP that results from the highly sorptive nature of DBCP. Extraction of DBCP from soil following soil sampling produces less variable and somewhat different results. DBCP concentrations which we detected in soil atmosphere are lower than those reported from soil samples (2, 4, 12). The discrepancy probably results from the completeness of the soil extraction method, which measures DBCP from soil particles, and the surface of organic materials as well as that which is in the soil solution. The atmosphere-sampling method reveals only the concentrations present in the soil air. From those we calculate concentrations in the soil solution based on equilibrium constants. This latter method appears to be more closely related to the concentration in which the nematode is actually bathed. However, equilibrium constants will vary from soil to soil depending on moisture conditions, ions in solution, etc.

CONCLUSION

DBCP added to a water-air interface is

eventually partitioned among the two phases depending on its Henry's Constant. The presence of soil particles in the water-air system further reduces DBCP concentrations in both, presumably a consequence of its reversible adsorption by the soil particles. The existence of intact roots in the same soil system results in further reduction of DBCP concentrations among each of the four phases, again a reversible sorption. The phenomenon of reversible sorption is substantiated in these tests by a reduction in DBCP concentrations without reducing DBCP persistence in the system. The above scenario has several implications on the practical use of DBCP. First, following chisel injections, DBCP tends to move through soil as a gradient rather than as a front. Second, concentrations of DBCP in the soil solution are buffered depending on soil conditions. This buffering apparently provides a degree of protection to those soil microorganisms exhibiting a higher threshold level to DBCP. Third, DBCP concentrations in a given soil profile can be expected to vary with numerous factors including soil depth, texture, moisture, temperature, pH, presence of roots, and hydraulic head. These conclusions appear consistent with findings of other workers (2, 4). Further, Hodges and Lear reported (2) that chisel injections made to soil without an additional water application can result in reduced DBCP concentrations in soil. This finding is consistent with ours and brings us to focus on a previous study (6) which indicated that DBCP is highly adsorbed to artificially dried soils. It is appropriate to speculate here that DBCP applications to any but moist to wet soils or those applications not soon followed by an irrigation or rain will likely result in an increased degree of irreversible adsorption.

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