

Potential Effect of Precipitation on the Efficacy of Soil Applied Insecticides – Reports from Preliminary Trials

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Introduction

In the last several years, there have been sporadic reports of the failure of insecticides applied against soil inhabiting insect pests of sugarbeet in multiple areas of the Red River Valley. In recent years these reports have included the active ingredients (AI) Terbufos (Counter[®], BASF), Chlorpyrifos (Lorsban[®], Dow AgroScience), and Zeta-Cypermethrin (Mustang Max[®], FMC Ag). These insecticides were applied against a number of insect pests including wireworms, sugarbeet root maggot and springtails and generally occur early in the season.

It is unlikely that these failures are due to resistance. Research conducted in the mid 1990's indicated that localized, regional resistance to Organophosphate insecticides may be developing in sugarbeet root maggot (Meagher & Wagner 1995, Carlson et al. 1996). However, subsequent work indicated that resistance was probably not developing in predictable patterns, nor was it re-occurring in the same geographical areas (Armstrong et al. 1997, 1998). Zeta-cypermethrin has not been used consistently enough in sugarbeet to have yet developed resistance.

Most of these incidents have been anecdotally linked to heavy precipitation events (MacRae, pers obs, Boetel pers comm, Anderson, pers comm) although no hard data exists to confirm these associations. However, the link is suspected so strongly that past management strategies recommended in the SBREB reports have included 2nd applications of granular insecticides if a heavy precipitation event occurs (Carlson et al. 1996). Heavy rains have also been linked with possible failures in insecticide trials in the RRV (Boetel et al. 1999). This may not be surprising. Chlorpyrifos, and Terbufos (Counter[®]) are Organophosphate insecticides and Zeta-Cypermethrin is a Synthetic Pyrethroid insecticide, all of which are water soluble. Chlorpyrifos is available in granular formulations to limit loss to precipitation, and Zeta-Cypermethrin, as with most Synthetic Pyrethroids, is reported as having relatively good soil binding properties. The potential for degradation of the a.i. in the soil of both Terbufos and Chlorpyrifos, has been noted in several different cropping and tillage systems (e.g. Terbufos – Gold et al. 1993, Kenimer et al. 1997, Racke et al. 1996; Chlorpyrifos - Rachman 1994, Sauer et al. 1990, Starret et al 1996, Volner & Klotz 1997). However, these characteristics have not been studied extensively either in agricultural or soil systems similar to those found in the Red River Valley. There is some information indicating that only limited movement of AI occurs with Cypermethrin, an older product related to Zeta-Cypermethrin (Agnihotri et al. 1989, Komal et al. 2001, Sakata et al. 1986). Cypermethrin is an isomer of Zeta-Cypermethrin and may be indicative of the latter's behavior in the soil. However, there is little published data directly addressing the movement of Zeta-Cypermethrin in the soil. The literature indicates that Terbufos, Chlorpyrifos, and Cypermethrin are all biodegraded in the soil (Sakata et al. 1986, Sikora et al. 1990, Rachman 1994, Racke et al. 1994, Volner & Klotz 1997).

The early season occurrence of the product failure incidents in sugarbeet seems to indicate that biodegradation is not the cause. The anecdotal reports of insecticide failure after heavy rains suggest another mechanism. Much of the damage done to sugarbeet by soil inhabiting insects occurs early in the season and shallow in the soil profile. The 'killing zone' for soil applied insecticides at this time is in the top 4"-6" of the soil. Should heavy rains move the AI of insecticides any deeper than this, even though their insecticidal properties may be quite active, they will literally not be in a position where they can cause insect mortality. Unfortunately, it is not uncommon for the Red River Valley to receive heavy precipitation events during this period of the season. It may be that minimal movement of AI is necessary. Some physical degradation of insecticides occurs in the soil naturally, if combined with movement caused by precipitation, the lowered rate of AI left in the 'killing zone' may not be sufficient to control the insect population.

Assessing the movement of insecticides in soil can prove problematic. In the field, the amount of labor necessary to adequately replicate experiments and control the application of precipitation can prove difficult. Microlysimeters, constructed from soil sampled intact from the field and placed into a plastic container, have been used in the lab to study soil characteristics in the root zone (Fermanich & Daniel 1990, Fermanich et al. 1990). But microlysimeters are expensive, complicated and actually used to investigate factors related to available soil moisture. Columns of soil have been used in the lab to study leaching rates (Flori et al. 1998). Columns of soil are sampled from fields of interest and used in the lab to model what is happening in specific field locations. This method has the benefit of being more economical than in-field studies and providing sufficient replications to be scientifically meaningful. Methods of analyzing for the presence of pesticides in both soil and water are well established and available. Gas-liquid chromatography (GC) has become a standard methodology of measuring insecticides in soil solutions (Baskarin & Bolan 1998) and is relatively inexpensive.

A series of preliminary laboratory trials were conducted to can assess if precipitation events have the potential to move Terbufos out of the killing zone. Terbufos was selected as an example because of its broad use in the Red River Valley.

Materials and Methods:

Soil cores were obtained from an untreated commercial field in St Thomas prior to planting. A Giddings Soil Probe fitted with plastic sleeves was used to obtain soil cores. Sampled soil columns were transported, kept and stored in the sleeves. Although cores were taken to a depth of 12" – 14", only the top 10" were used in the trials.

Powder funnels were attached to the bottom of the sleeves using silicon sealant. The sleeves were then placed into racks and water was placed on top of the soil in the sleeves to simulate precipitation. Simulated precipitation equivalent to 1", 2", 3", 4", 6", and 8" rainfalls was used. Water was added slowly to allow for the expansion within the sleeve of soil as it adsorbed water. This also prevented water from simply running down the outside edge of the soil core into the flask below. Sleeves were left for 24 h, and water traveling through the soil column was collected in a flask.

Collected water samples were prepared for analyses using a modification of EPA 608 (US EPA 1992), a well established methodology for GC analysis of organophosphate compounds (e.g. Terbufos) in liquid samples. Collected water was analyzed for the presence of Terbufos using Gas-Liquid Chromatography (GC). The GC used was a Varian 3500 with a Flame Ionization Detector (a good general purpose detector, suitable for most organic compounds). A GC separates out a compound and runs it over a detector over a period of time; different molecules will volatilize at different rates and encounter the detector at different times in the run. Different compounds, therefore, can be identified based on when in the run they are encountered by the detector (in the chromatograph output, these different incidents are indicated by retention peaks, or spikes in the graph at different times in the run). The size of the peak can be used to estimate the amount of compound in the sample. Prior to analysis of the collected water samples, a standard technical grade Terbufos in Hexane solution was run to acquire the retention peaks for Terbufos. This standard was prepared so that the amount of Terbufos in the standard would be equal to the total amount of AI added to each soil core. The peak this standard would provide should, therefore, be equal to that obtained from a collected water sample in which all of the Terbufos had been displaced through the soil core. If retention peaks similar to the Terbufos standard were encountered in the collected water samples, it would be indicative of the presence of Terbufos. Because of time and economic restraints, soil from the core itself was not assessed for the amount of AI remaining in the 'killing zone'. Each of the simulated rainfall treatments was replicated 3 times. Unfortunately, the output from the GC used was not downloadable to another format and digital scans had to be obtained of the output graphs.

Results and Discussion

Chromatographic analysis of the technical grade Turbufos standard indicated a distinct retention peak at approximately 10.313 – 10.672 minutes (fig. 1). The water recovered from the 1" simulated rainfall showed no presence of Terbufos (fig. 2). In fact, very little water was recovered from this treatment. Analysis of the 2" and 4" treatments both showed the presence of Terbufos in the collected water (figs 3 & 4). The retention peak for the 2" treatment came at ~10.443 minutes. This peak was very small, and while it does indicate Terbufos was present in the water collected, it was probably a very small amount. A 2" precipitation event would probably not affect the efficacy of a Terbufos application. The retention peak for the 4" sample occurred at ~10.443 minutes. This peak was also small, but compared to the peak of the Terbufos standard, it was measurable. Although statistical analyses were not performed, the retention peak in the 4" treatment visually appears to be about 1/5 as large a peak as that of the Terbufos standard; a 20% reduction in AI may very well impact the efficacy of an insecticide. The results for 6" of simulated rainfall were more variable (fig. 5). A peak did occur at ~10.593 minutes, but it was smaller than that encountered for the 4" treatment. This is counter-intuitive; it was expected that the greater amount of water traveling through the soil column in the 6" treatment would result in larger amounts of Terbufos being moved. It should be noted that these results may be due to problems encountered with the GC later in the trial. Even excluding the data from the 6" simulated rainfall treatment, we have indications that precipitation can move Terbufos out of the killing zone, and, while not a lot of AI is involved, it may be sufficient to impact the efficacy of the insecticide.

It should be recognized that these results are preliminary; a direct comparison between treated and untreated soil cores was not possible due to economic constraints. We interpreted the presence of retention peaks similar to those found in the Terbufos standard as evidence for the presence of Terbufos in the collected water samples (although this is a sound assumption given the nature of the analyses). In addition, these preliminary trials only measured what Terbufos was present in water that had percolated through the entire 10" soil core; the results do not reflect what Terbufos may be bound to the soil below the killing zone. These results suggest that Terbufos may be moved out of the 'killing zone' but do not address amounts or what levels of precipitation may lead to the need for re-application. Further, more detailed trials is needed to ascertain if the reduction in AI in the killing zone is sufficient to decrease the efficacy of Terbufos and if this is the case with other soil applied insecticides as well.

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Method File : C:\STAR\STARTUP1.MTH
Sample ID : Manual Sample

Injection Date: 17-SEP-5 12:16 pm
~~0:10 AM~~

Operator : ch Detector Type: ADCB (1 Volt)
Workstation: MS-DOS_5 Bus Address : 16
Instrument : Varian Star #1 Sample Rate : 10.00 Hz
Channel : A = A Run Time : 21.652 min

***** Varian GC Star Workstation ***** Rev. A.05/23/91 *****

Chart Speed = 0.85 cm/min Attenuation = 4524 Zero Offset = -1%
Start Time = 0.000 min End Time = 21.652 min Sig / Tick = 1.00

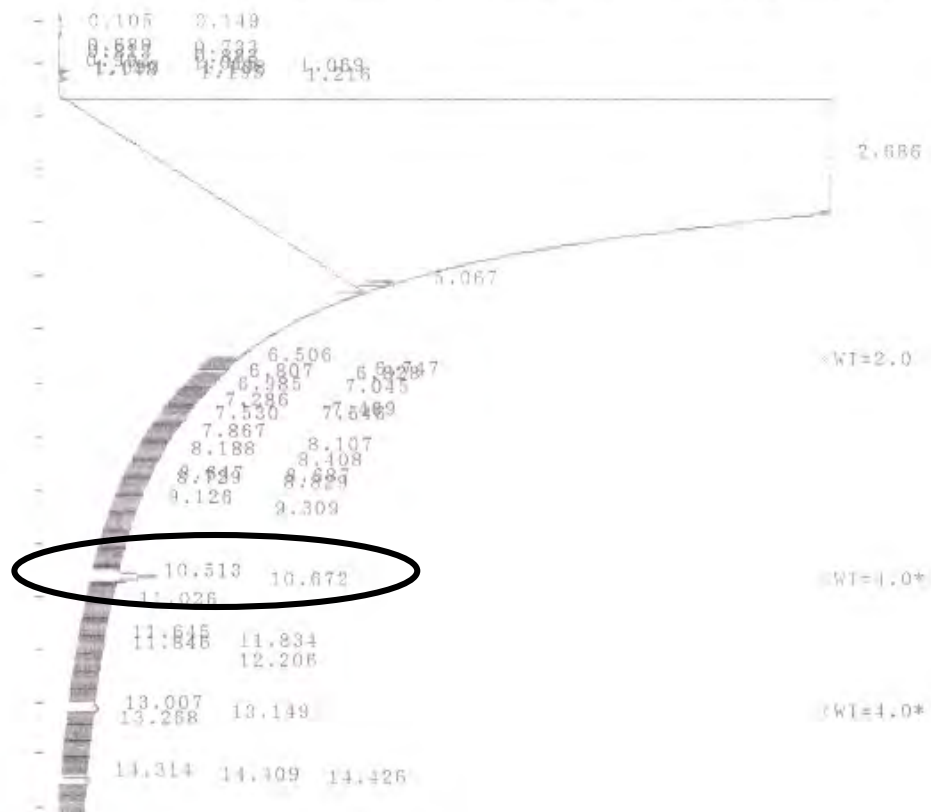


Figure 1. Gas-Liquid Chromatograph for Terbufos Hexane standard solution. Retention peak at 10.313 – 10.672 minutes represents presence of Terbufos according to methodology EPA 608 (USEPA 1992).

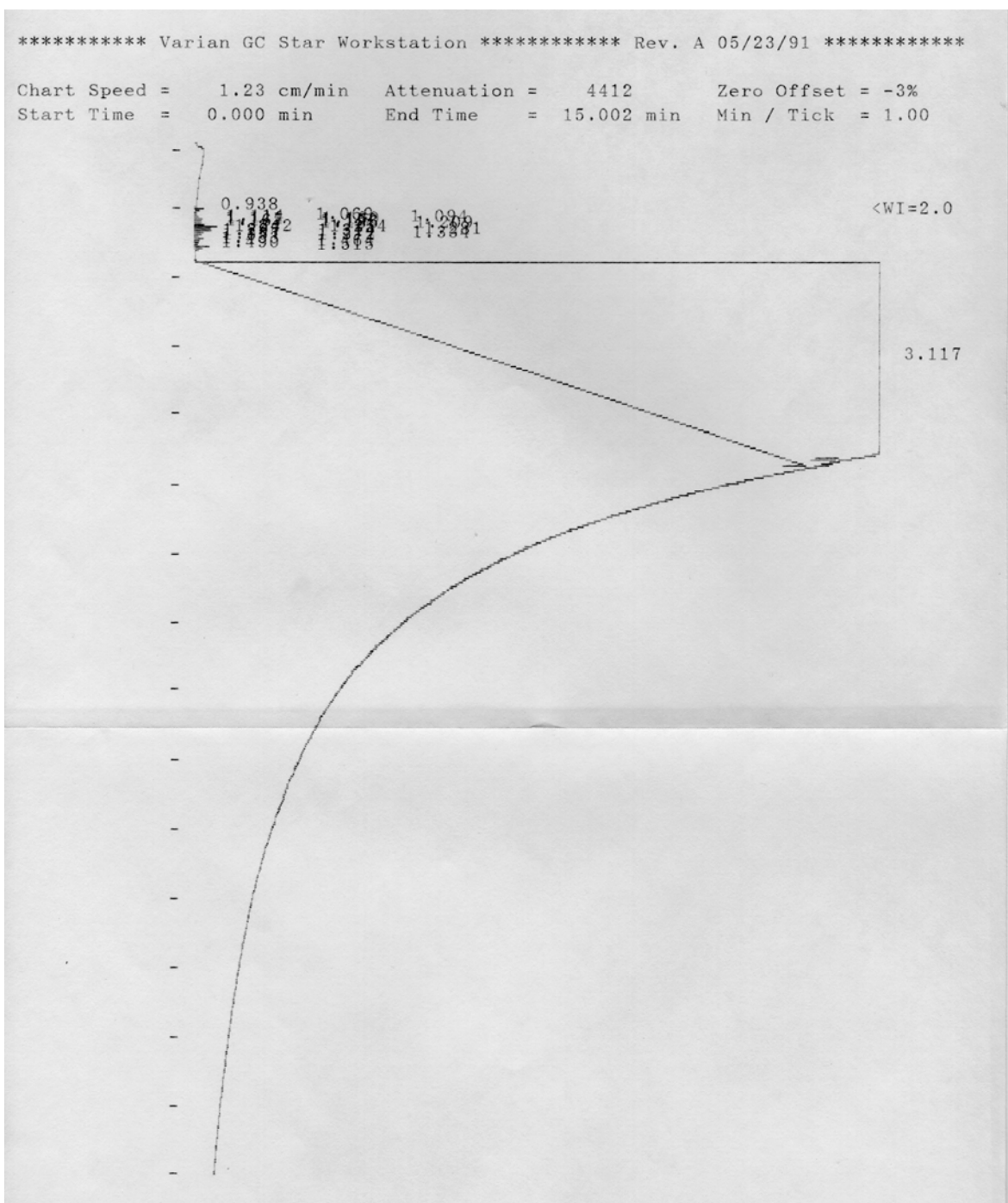


Figure 2. Gas-Liquid Chromatograph for water sample collected under from 1" simulated rainfall treatment. The lack of any retention peak after 3.117 minutes denotes the absence of Terbufos from this sample.

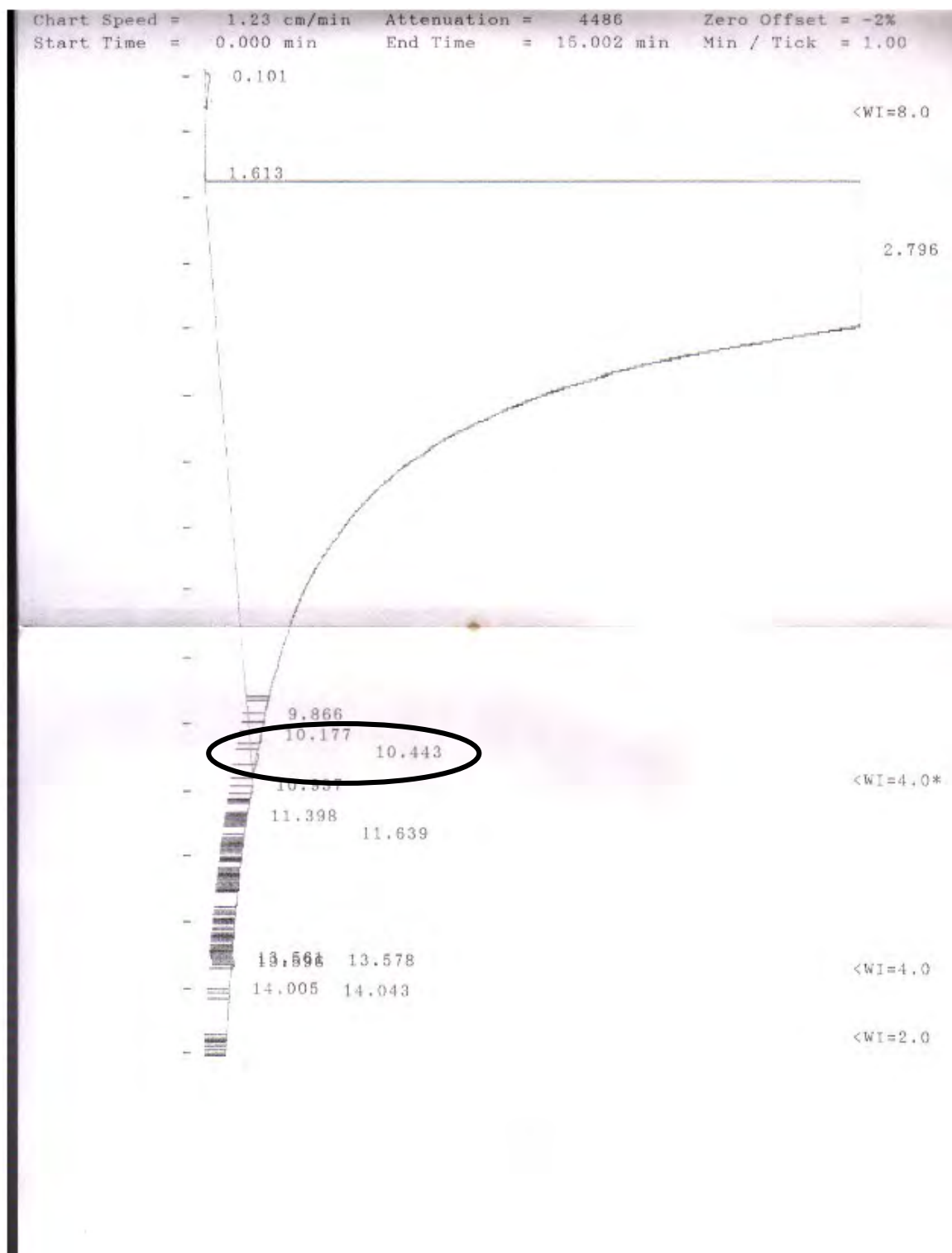


Figure 3. Gas-Liquid Chromatograph for water sample collected from 2" simulated rainfall treatment. Note retention peak at 10.443, interpreted as indicating presence of Terbufos in this sample. The small size of the peak, however, indicates not much material is present.

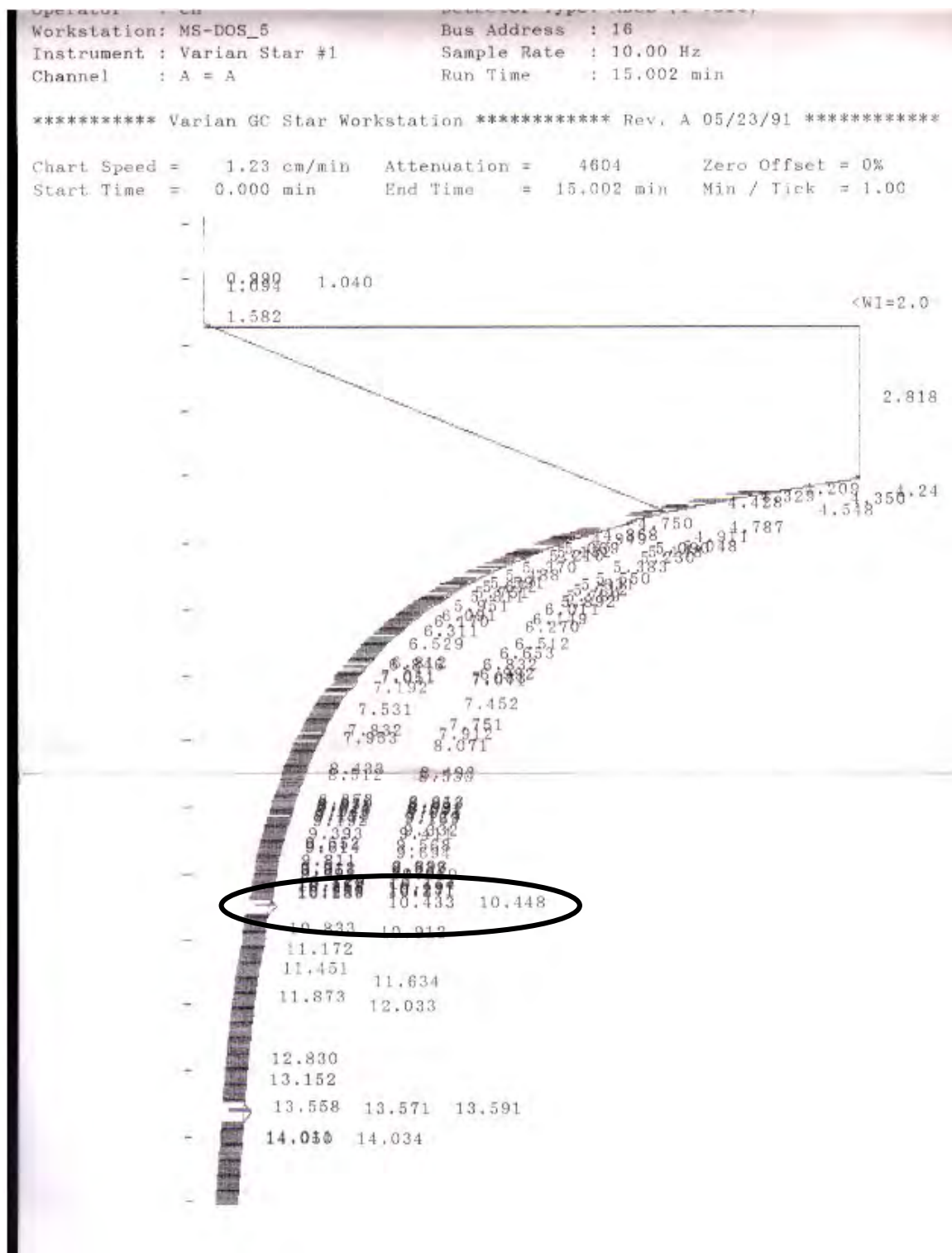


Figure 4. Gas-Liquid Chromatograph for water sample collected from 4" simulated rainfall treatment. Note retention peak at 10.433 – 10.448 minutes, interpreted as indicating presence of Terbufos in the sample. The peak is approximately 1/5 the size of the Terbufos standard peak, indicating perhaps as much as 20% of the Terbufos in this treatment was present in the collected water sample.

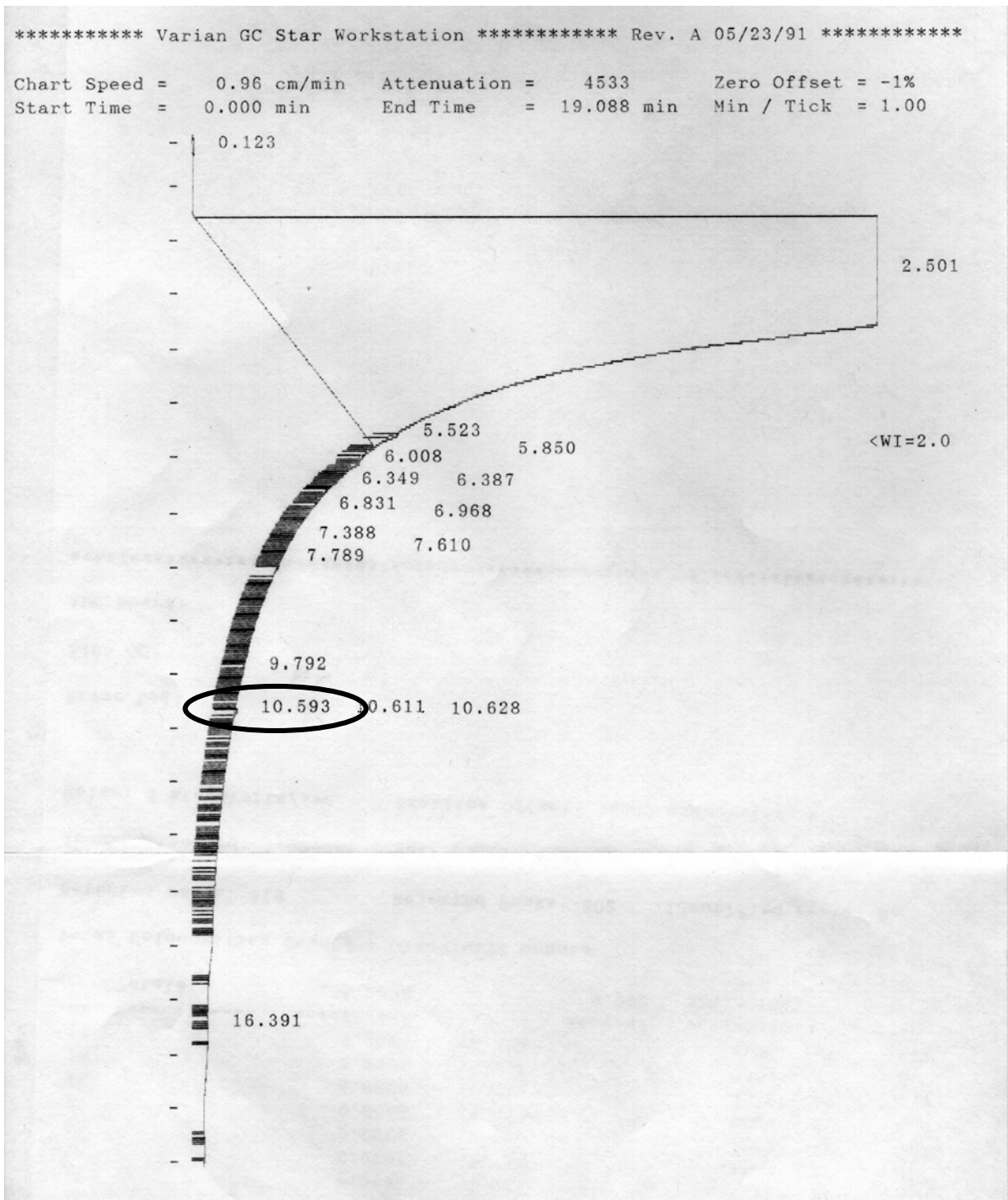


Figure 5. Gas-Liquid Chromatograph for water sample collected from 6" simulated rainfall treatment. Note the retention peak at 10.593 minutes, interpreted as indicating presence of Terbufos in the sample. Although this peak is smaller than the 4" treatment, this may be due to problems encountered with the GC during this set of trials.