

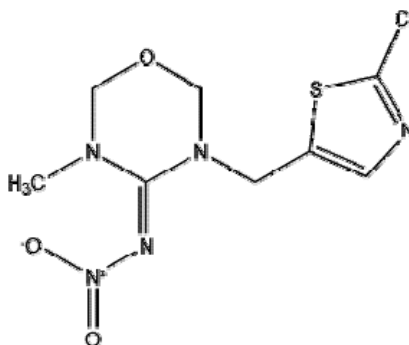
Ground-Water Leaching Potential of Thiamethoxam

Introduction:

Thiamethoxam, (EZ)-3-(2-chloro-1,3-thiazol-5-ylmethyl)-5-methyl-1,3,5-oxadiazinan-4-ylidene(nitro)amine (CAS No. 153719-23-4), is a commercial neonicotinoid insecticide acting on insect nicotinic acetylcholine receptors. It is an insecticide from thianicotinyl subclass, providing effective control of various sucking and chewing insects on agricultural crops. It is known as a neonicotinoid precursor for clothianidin which shows high activity as agonists on isolated neurons in a low dose concentration, e.g., 30 nM. Due to its convenience (e.g., flexible application methods) and low cost (e.g., long-lasting residual activity), the compound has been widely used in modern agriculture. However, the European Union (in April 2013) has temporarily restricted the use of this compound including imidacloprid and clothianidin to crops that are attractive to bees due to an unacceptably high risk to them.

Selected Physical/Chemical Properties of Thiamethoxam:

Chemical structure:



Literature data

Chemical formula:	C ₈ H ₁₀ ClN ₅ O ₃ S
Molecular mass:	291.71 g/mole
Physical state:	Crystalline, odorless powder
Water solubility (at 20°C):	4100 mg/L
Log P _{ow} (at pH 7, 20°C):	-0.13
Vapor pressure (at 25°C):	6.60 × 10 ⁻⁰⁶ mPa
Henry law constant (at 25°C):	4.70 × 10 ⁻¹⁰ Pa·m ³ /mol
(at 20°C):	1.93 × 10 ⁻¹³ dimensionless
K _{oc} :	56.2–245 (mean 123.7) mL/g
Soil degradation half-life (lab):	33.1–697.5 (registrant) ppm
	39–121 (typical 50) days
	324.7 (registrant) days
Freundlich coefficients (K _f):	0.22 – 3.64 (registrant)
Freundlich coefficient (1/n):	0.80 – 0.93 (registrant)
GUS index:	3.82 (High leachability)
SCI-GROW index (ppb) for 1 kg/ha dose:	3.14 × 10 ⁺⁰⁰ µg/L
Potential for particle bound transport index:	Medium

Environmental Fate Data:

Hydrolysis

The stability of the compound (2-¹⁴C-thiazolyl CGA 293343) was evaluated in approximately 10 ppm buffer solutions at various pH values and temperatures under sterile, dark conditions. For the duration of the experiment, the compound showed the stability at pH values of 1 and 5 in 60°C and at the pH buffer in 25°C, whereas a rapid degradation was observed at all temperatures (25, 45, and 60°C). The degradation rate of the compound seemed to be highly dependent both on pH and temperature, and the estimated half-life of the least stable condition (at pH 9 in 60°C) was 0.12 days. Three major metabolites under unstable conditions were CGA-355190, CGA-309335, and NOA-404617.

Registrant also measured the stability of the compound (2-¹⁴C-Guanidine CGA 293343) with the same condition as mentioned above. The degradation rate of the compound was also variable both between pH values and between temperatures, showing most stability at pH 5 in 60°C and least stability at pH 9 in 60°C (0.12 days). CGA-355190 and NOA-404617 were identified as two major degradates of the parent compound, accounting for around 60% and 28% of the applied dose, respectively.

Photodegradation in Water (from literature)

Even though the registrant did not provide information on aqueous photolysis, we found from the literature that the thiamethoxam, 4H-1,3,5-oxadiazin-2-imine, 3-[(2-chloro-5-thiazolyl)methyl]tetrahydro-5-methyl-N-nitro metabolizes significantly under photolytic conditions, in sterile acetate buffer (at pH 5.0) using artificial sunlight. In addition, the volatile components of the parent compound were shown to be continuously degraded by traps containing cyclohexylamine at room temperature.

Aerobic Degradation Studies in Soils

Aerobic soil metabolism studies were conducted using viable and sterile (clay loam) soil under aerobic lab conditions. The compound (¹⁴C-Guanidine CGA 293343) was applied to both soils at a rate of 0.1 ppm which corresponded to the proposed maximum field application rate. 50 g of dry weight equivalents of soils were used in this study, and the soil samples after dosing were incubated at 75% of 0.3 bar soil moisture tension at 25°C in the dark condition. Volatile products were measured using a purge-and-trap method which contained two KOH traps (10% aqueous) and one ethylene glycol trap. Soil and volatile traps were quantified at various time intervals over 12 months.

The parent compound showed a faster metabolism in aerobic viable soil than in sterile soil, although its degradation pattern was the same for both soils. This result indicated that some microbes involved in the degradation of the parent compound. The estimated half-life values were 101.34 days for viable soil and 686.28 days for sterile soil. The parent compound degraded to CGA-355190, CGA-282149, and CGA-353968, and CGA-322704, which showed 23.09% at 6 months, 6.83% at 6 months, 3.79% at 12 months (only shown in the viable soil), and 1.98% at 3 months of applied radioactivity, respectively. The estimated half-life of the main degradate CGA-355190 was 459 days in the viable soil. Figure 1 showed the proposed pathway of the parent compound in two soils under aerobic conditions, where three competitive routes of

metabolism such as 1) cleavage of N-NO₂ group, the opening of 2) oxadiazinyl ring and 3) bridge cleavage are mainly suggested.

Registrant also carried out another aerobic soil metabolism study using four sandy loam soils. In this study, the parent compound of ¹⁴C-Guanidine CGA 293343 was applied to four soils at an average rate of 0.09 ppm for kinetic soil sets (i.e., kinetic viable and kinetic sterile soils) and 4.9 ppm for bulk soil sets (i.e., bulk viable and bulk sterile soils). Here, bulk soils sets were prepared for major degradates isolation, whereas the kinetic soil sets were used to observe degradation pattern under field dose rates. 50 g and 100 g of dry weight equivalents of soils were used for the kinetic soil sets and for the bulk soil sets, respectively. The soil samples after dosing were incubated at 75% of 0.3 bar soil moisture tension at 25°C in the dark condition. Volatile products were again measured using a purge-and-trap method which contained foam plugs, ethylene glycol, and aqueous KOH traps. Soil and volatile traps were quantified at various time intervals over 12 months.

The parent compound showed biphasic kinetics (i.e., initial rapid and the second slow degradation) in kinetic viable soil. The primary and secondary half-life estimated were 7.01 days and 521 days, and the average half-life during the full incubation period was 249 days. The other three soils showed apparent first order kinetics of the parent compound, and the estimated half-life values were 318 days for kinetic sterile soil, 241 days for bulk viable soil, and 379 days for bulk sterile soil. No significant metabolite was accumulated for the duration of the study, and all intermediates accounted for less than 10% of applied radioactivity. Figure 2 showed the proposed pathway of the parent compound in aerobic sandy loam soil, CGA-322704, CGA-282149, CGA-355190, and CGA-353968.

An aerobic soil metabolism was studied by the registrant using four sandy loam soils with ¹⁴C-Thiazole CGA 293343. Here, four California soil sets, as mentioned above, were again prepared to evaluate degradation patterns and isolate major degradates of the parent compound. All experimental conditions were exactly the same as the study right above.

The parent compound showed biphasic kinetics in kinetic viable soil. The primary and secondary half-life estimated were 4.7 days and 471 days, and the average half-life during the full incubation period was 353 days. The other three soils showed apparent first order kinetics of the parent compound, and the estimated half-life values were 286 days for kinetic sterile soil, 254 days for bulk viable soil, and 379 days for bulk sterile soil. No significant metabolite was accumulated for the duration of the study, and all intermediates accounted for less than 10% of applied radioactivity. Figure 3 showed the proposed pathway of the parent compound in aerobic sandy loam soil and the degradation pattern under the sterile condition was similar to that of the hydrolysis study.

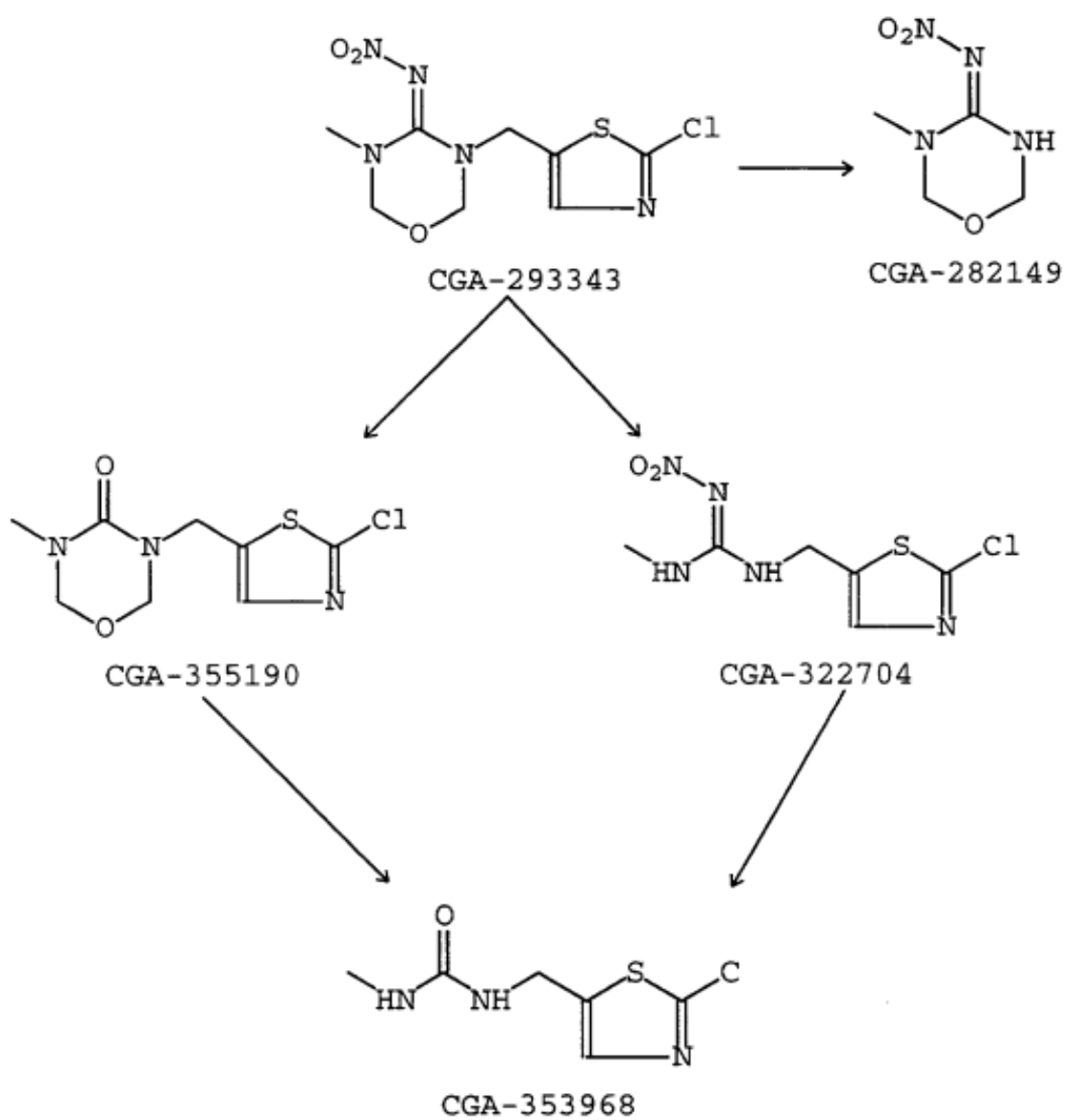


Figure 1. The proposed pathway for metabolism of the parent compound (^{14}C -Guanidine CGA 293343) in viable and sterile (clay loam) soils under aerobic conditions.

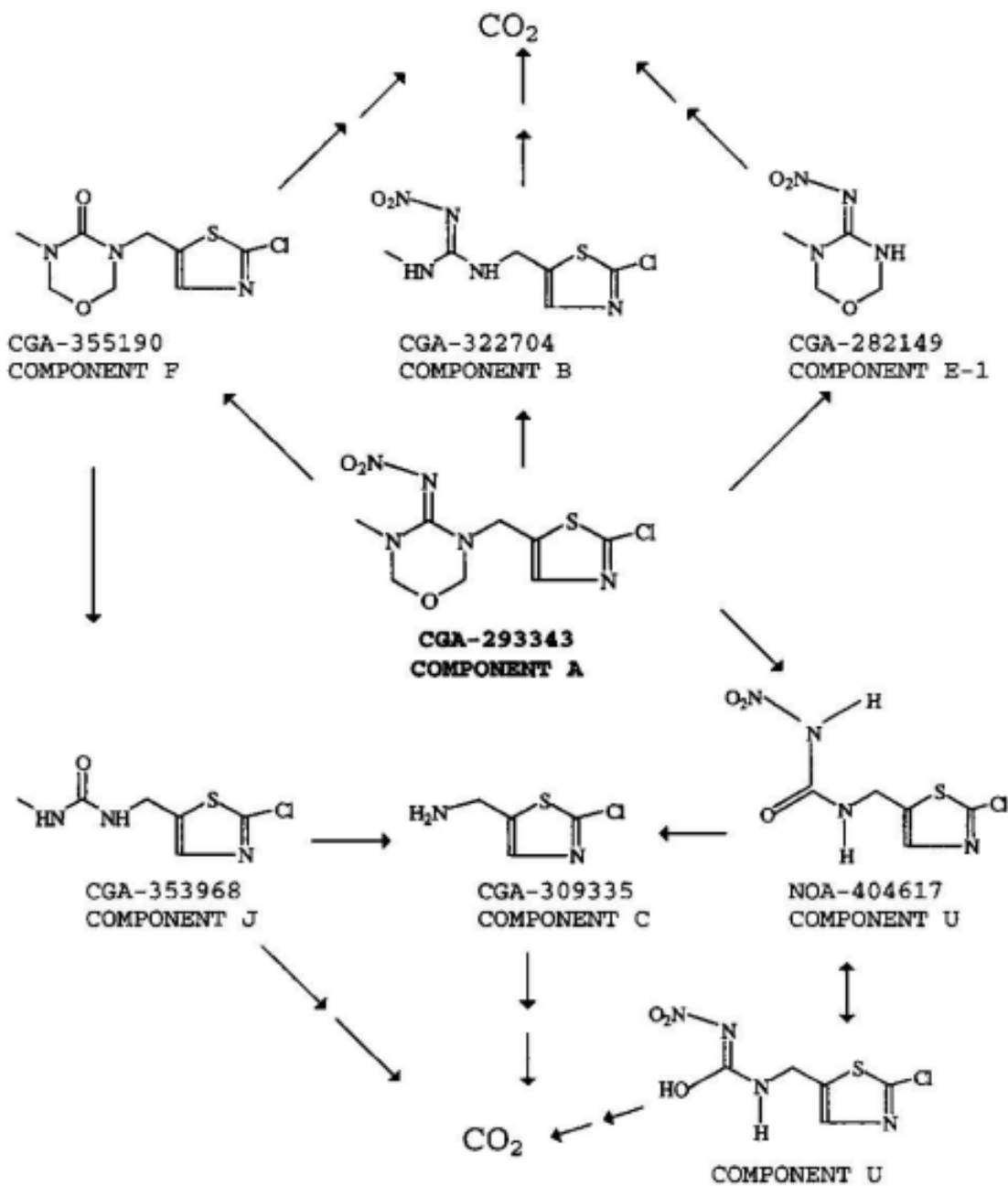


Figure 2. The proposed pathway for metabolism of the parent compound (¹⁴C-Guanidine CGA 293343) in California sandy loam soils under aerobic conditions.

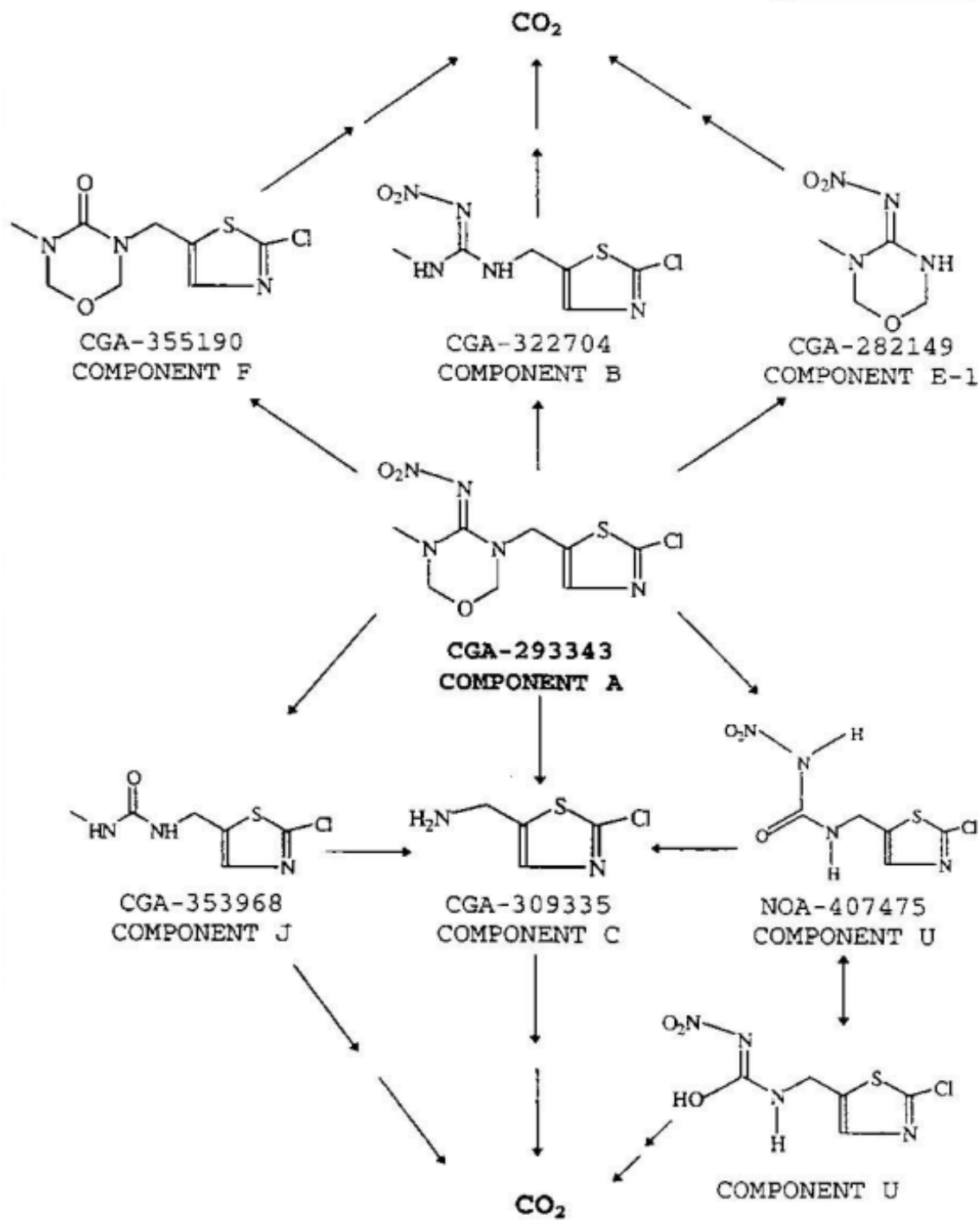


Figure 3. The proposed pathway for metabolism of the parent compound (¹⁴C-Thiazole CGA 293343) in California sandy loam soils under aerobic conditions.

Adsorption and Desorption to Soil

The registrant tested adsorption and desorption characteristic of the compound (^{14}C -Guanidine CGA 293343) using six soils varying in texture, pH, cation exchange capacity, and percent organic matter (see Table 1). A ratio of 7 g of soil to 12 mL of solution was identified as optimal condition from the preliminary study, where the time needed to reach equilibrium was 19 hours. Four aqueous test solutions of the compound (at concentrations of 0.11, 0.94, 2.33, and 4.71 ppm) were prepared using 0.01 M calcium chloride. Then, the equilibrium study was conducted at 25°C in a shaking bath with a soil to test solution ratio of 7 to 12 in 50 mL Teflon centrifuge tubes, which was shaken at 125-140 rev/min for the duration of the study. After 19 hours of shaking, the tubes were centrifuged at 2500 rpm for 10 minutes, and the adsorption supernatant was decanted and radioassayed. For desorption study, fresh 0.01 M calcium chloride was added to the samples to reach original sample weight after dosing, which was placed again in a shaking bath for shaking during 19 hours. Single desorption study was conducted for 0.11, 0.94, and 2.33 ppm samples, whereas three serial desorptions were applied to the 4.71 ppm samples.

Table 1. Summary characteristics of the soils employed in this study.

	BD g/cm ³	pH –	CEC Meg/100 g	OM %	Classification –
629W-2 (Carman, Manitoba)	1.01	6.2	18.2	5.1	Sandy clay loam
629W-4 (Plattsville, Ontario)	1.16	6.2	10.0	2.9	Loam
627W-13 (Sanger, CA)	1.25	7.6	8.9	0.7	Sandy loam
627W-14 (Andersonville, GA)	1.45	5.4	3.7	0.9	Sand
627W-17 (Livingston, NY)	1.07	7.2	10.5	2.9	Loam
627W-19 (Livingston, NY)	1.09	6.5	16.8	4.1	Silty clay loam

¹ BD = Bulk density, CEC = cation exchange capacity, and OM = organic matter.

Experimental data were analyzed using the Freundlich isotherm model. In adsorption study, the estimated K values varied between 0.22 and 2.32 for six soils. Based on organic carbon content, the K_{oc} values estimated varied between 33.1 and 176.7. Similarly, in desorption study, the estimated K values varied between 0.90 and 3.64 for six soils. The estimated K_{oc} values in desorption test also varied between 72.1 and 697.5. Based on the results of the estimated K_{oc} values, the registrant concluded that the compound had medium to high mobility in the soils studied. And the compound, once adsorbed to soils, was not expected to be removed to the aqueous phase because the desorption study showed higher K_{oc} values than those of adsorption study.

Table 2. Sorption and desorption data of the compound using six soils.

Soil type	Adsorption				Desorption (1st)			
	K	K_{oc}	$1/n$	r^2	K	K_{oc}	$1/n$	r^2
629W-2 (Carman, Manitoba)	2.32	77.2	0.8334	1.0000	3.64	121.3	0.8258	0.9989
629W-4 (Plattsville, Ontario)	0.90	53.1	0.8163	0.9999	2.56	150.6	0.8724	0.9965
627W-13 (Sanger, CA)	0.71	176.7	0.8389	0.9994	2.79	697.5	0.9565	0.9905

627W-14 (Andersonville, GA)	0.22	43.0	0.8613	0.9992	0.90	180.0	0.9279	0.9989
627W-17 (Livingston, NY)	0.65	38.3	0.7956	0.9996	2.28	134.1	0.8469	0.9991
627W-19 (Livingston, NY)	0.75	33.1	0.8788	0.9996	1.73	72.1	0.8666	0.9984
Mean	0.93	70.2	0.8374	0.9996	2.32	225.9	0.8827	0.9971

Evaluation of Leaching Potential to Ground Water for Thiamethoxam

Leaching potential of the parent compound was examined in soils ($n=2789$) on Oahu, Hawaii. Since there is difference between literature values and registrant's recommended values for the K_{oc} and half-life, we have run the CLERS model twice to assess leaching potential of the parent. The recommended mean and standard deviation in literature were 0.124 and 0.134 m^3/kg for K_{oc} and 50 and 58.0 days for half-life. And those values recommended by registrant were determined as 0.148 and 0.181 m^3/kg for K_{oc} and 324.7 and 151.5 days for half-life. Here, the standard deviation of two values in literature was estimated from the two extremes, whereas that of registrant was determined using all laboratory studies.

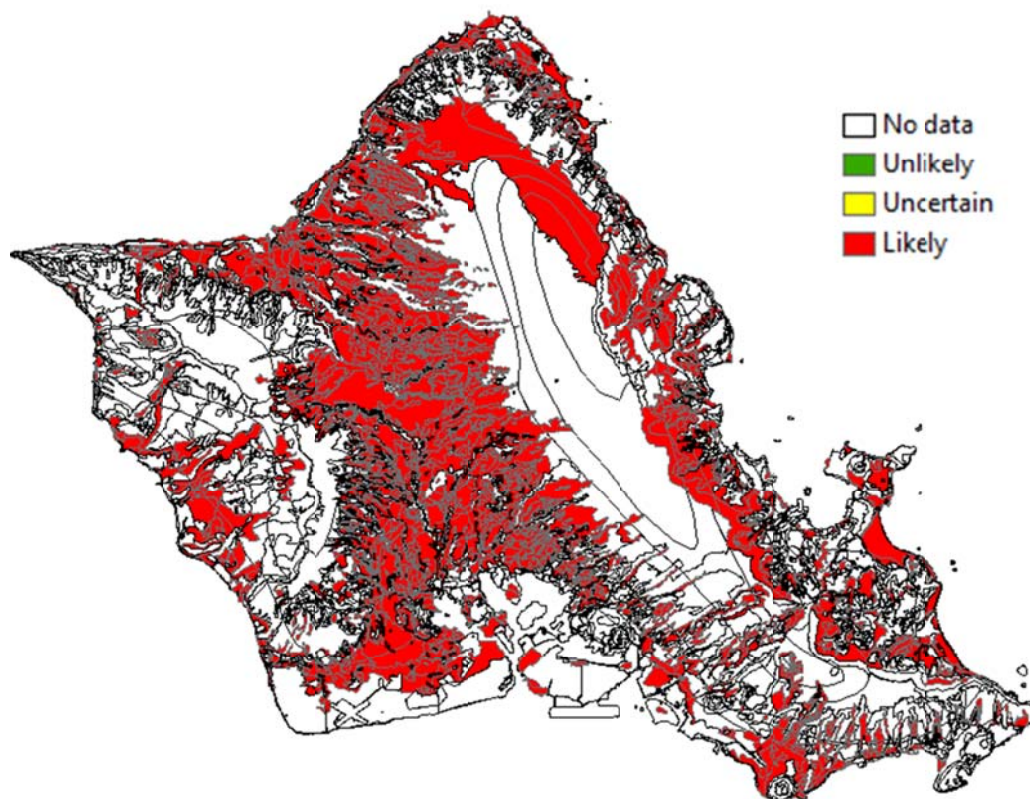


Figure 2. Leaching potential of the parent compound (on Oahu, Hawaii) using literature values in CLERS model.

Table 6. Summary statistics of main evaluation criteria in CLERS model ($n=2,789$)¹.

	Literature				Registrant			
	AFR	CVAFR	RF	CVRF	AFR	CVAFR	RF	CVRF
Mean	4.91	0.30	9.78	0.28	3.20	0.30	11.51	0.29
SD	1.26	0.05	3.76	0.13	1.26	0.05	4.50	0.13

¹ Abbreviation: AFR– revised attenuation factor; CV– coefficient of variance, i.e., uncertainty band; RF– retardation factor; SD– standard deviation; n – the total number of soil polygons.

Figure 4 shows a leaching potential of the parent compound on Oahu, Hawaii determined by literature values in CLERS model. Exactly, the same leaching pattern is also observed using registrant’s recommended values. As shown in the figure, the leaching potential of the compound is high on Oahu, Hawaii, when compared to two reference chemicals of leacher and non-leacher. Table 6 also shows a descriptive statistics of main evaluation criteria in CLERS model. From the table, it is determined that no significant difference in revised attenuation (AFR) and retardation factors (RF) was observed for both literature values and registrant’s recommended values in CLERS model. In both model runs, RF values are low, indicating the compound is less bound onto soil surface. Volatilization of the compound also does not likely occur in soils due to a very low Henry's law constant. Based on these results, it can be suggested that the compound is considered as a potential leacher in Hawaii. Thus, adequate use plans need to be developed for its use. Additionally, its label rates and toxicity should be considered. As it is used at low doses, despite its leaching potential, other benefits may be considered. In addition, if the compound is to be used in greenhouse conditions, it may be looked favorably.

References

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Appendix A. Additional CLERS model runs for remaining islands in Hawaii.

A1. Maui Island, Hawaii

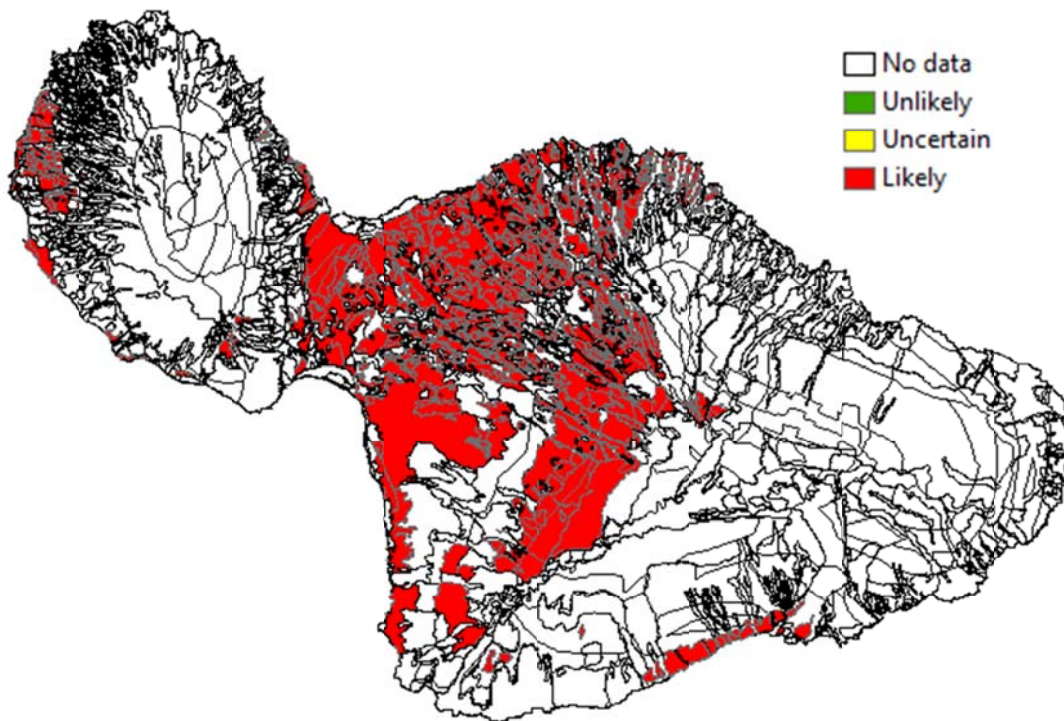


Figure A1. Leaching potential of the parent compound (on Maui Island, Hawaii) using literature values in CLERS model. Exactly, the same pattern is observed in CLERS model run using registrant's recommended values.

Table A1. Summary statistics of main evaluation criteria in CLERS model for Maui Island, Hawaii ($n=1,095$)¹.

	Literature				Registrant			
	AFR	CVAFR	RF	CVRF	AFR	CVAFR	RF	CVRF
Mean	5.02	0.29	12.66	0.25	3.31	0.29	14.95	0.25
SD	0.80	0.03	5.86	0.12	0.80	0.03	7.02	0.13

¹ Abbreviation: AFR– revised attenuation factor; CV– coefficient of variance, i.e., uncertainty band; RF– retardation factor; SD– standard deviation; n – the total number of soil polygons, where bulk density is greater than 0.

A2. Molokai Island, Hawaii

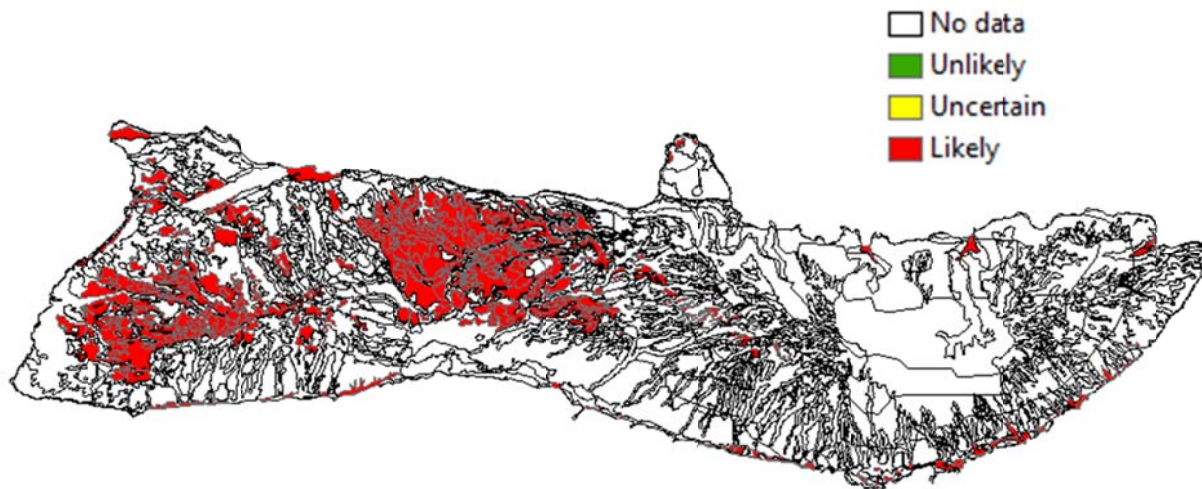


Figure A2. Leaching potential of the parent compound (on Molokai Island, Hawaii) using literature values in CLERS model. Exactly, the same pattern is observed in CLERS model run using registrant’s recommended values.

Table A2. Summary statistics of main evaluation criteria in CLERS model for Molokai Island, Hawaii ($n=515$)¹.

	Literature				Registrant			
	AFR	CVAFR	RF	CVRF	AFR	CVAFR	RF	CVRF
Mean	5.25	0.85	9.43	0.26	3.54	0.85	11.10	0.26
SD	0.46	8.15	5.94	0.11	0.46	8.15	7.11	0.11

¹ Abbreviation: AFR– revised attenuation factor; CV– coefficient of variance, i.e., uncertainty band; RF– retardation factor; SD– standard deviation; n – the total number of soil polygons, where bulk density is greater than 0.

A3. Kauai Island, Hawaii

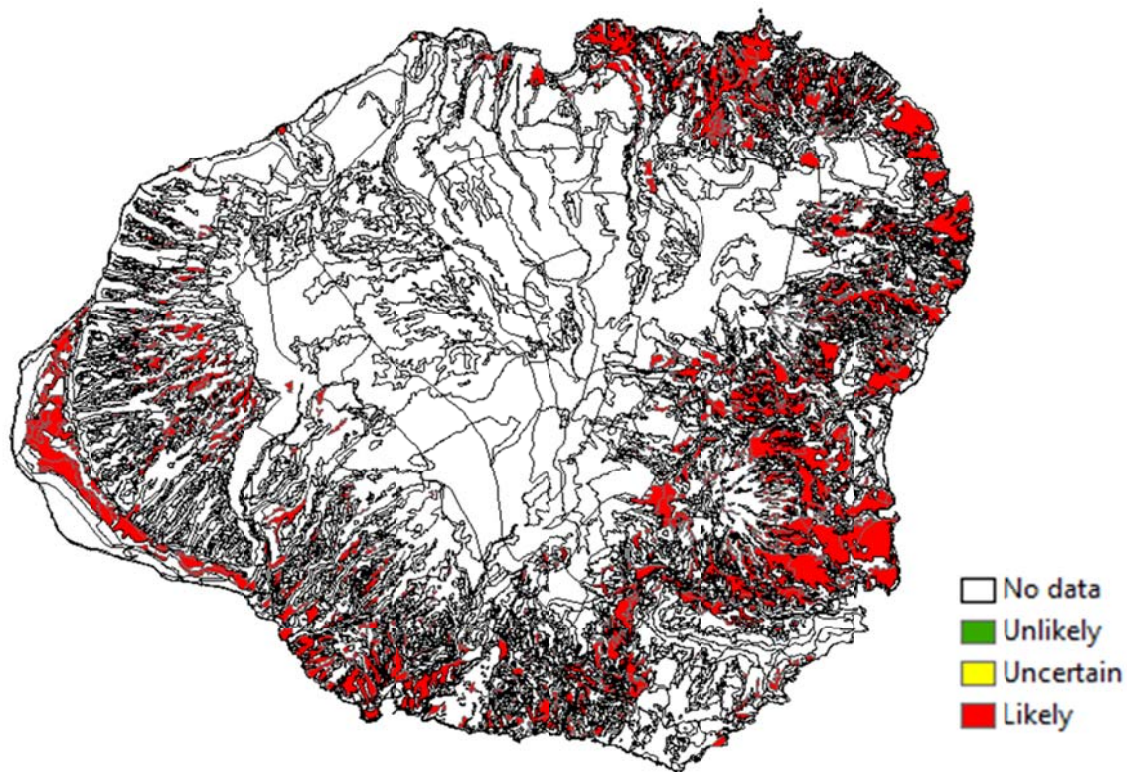


Figure A3. Leaching potential of the parent compound (on Kauai Island, Hawaii) using literature values in CLERS model. Exactly, the same pattern is observed in CLERS model run using registrant's recommended values.

Table A3. Summary statistics of main evaluation criteria in CLERS model for Kauai Island, Hawaii ($n=1,236$)¹.

	Literature				Registrant			
	AFR	CVAFR	RF	CVRF	AFR	CVAFR	RF	CVRF
Mean	5.63	1.04	12.77	0.21	3.93	1.04	15.09	0.21
SD	0.91	1.70	4.82	0.10	0.91	1.70	5.77	0.10

¹ Abbreviation: AFR– revised attenuation factor; CV– coefficient of variance, i.e., uncertainty band; RF– retardation factor; SD– standard deviation; n – the total number of soil polygons, where bulk density is greater than 0.

A4. Hawaii Island, Hawaii

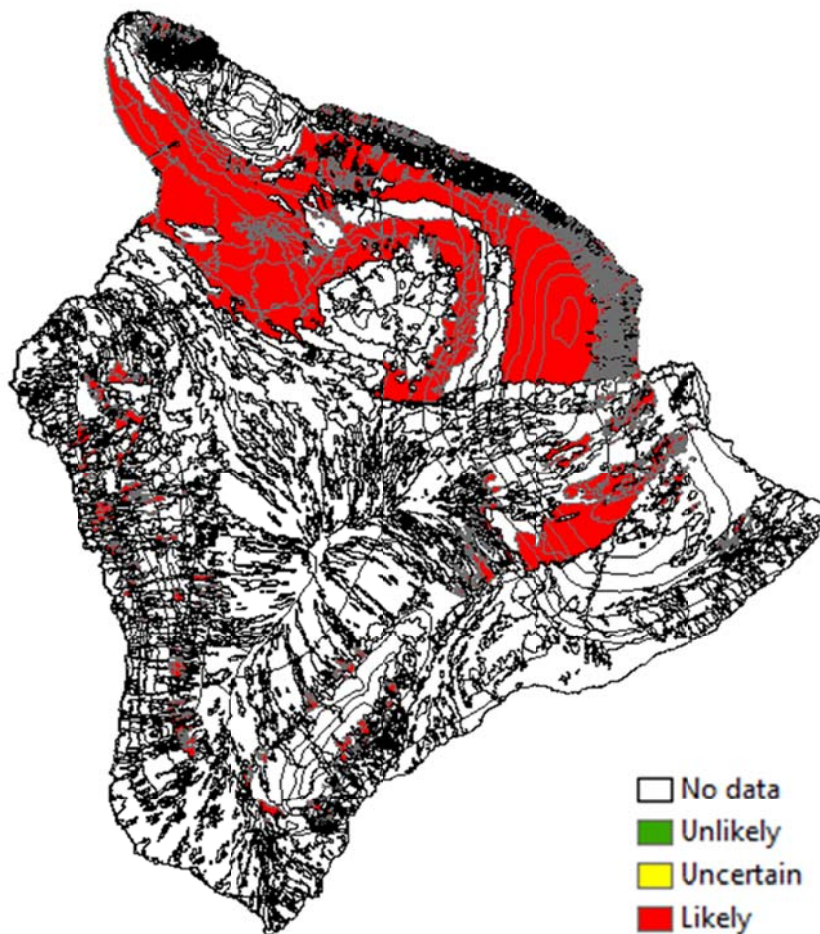


Figure A4. Leaching potential of the parent compound (on Hawaii Island, Hawaii) using literature values in CLERS model. Exactly, the same pattern is observed in CLERS model run using registrant's recommended values.

Table A4. Summary statistics of main evaluation criteria in CLERS model for Hawaii Island, Hawaii ($n=2,101$)¹.

	Literature				Registrant			
	AFR	CVAFR	RF	CVRF	AFR	CVAFR	RF	CVRF
Mean	4.06	0.07	13.44	0.37	2.36	0.07	15.89	0.38
SD	1.53	0.09	5.01	0.14	1.53	0.09	6.00	0.14

¹ Abbreviation: AFR– revised attenuation factor; CV– coefficient of variance, i.e., uncertainty band; RF– retardation factor; SD– standard deviation; n – the total number of soil polygons, where bulk density is greater than 0.