EFFECT OF MULCH RESIDUE ON THE USE OF ALTERNATIVE HERBICIDES AND SUGARCANE YIELD[1]

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INTRODUCTION

The effect of surface crop residues on interception, subsequent wash-off, and movement of herbicide in the soil profile is the primary focus associated with conservation measures in today's agriculture. Various forms of soil conservation are highly recommended in an effort to reduce soil losses and runoff of applied agricultural chemicals. Conservation production systems are characterized by the presence of mulch residue left on the soil surface to protect it from water and soil erosion. Over the last five years, the sugarcane industry is shifting toward an alternative harvesting system. The traditional harvest system involves the use of soldier harvesters where the whole stalks of sugarcane plants are cut, piled, burned, picked up, and transported to the mill. The new system involves the use of a combine harvester that cuts the cane stalks into billets, which are directly loaded into wagons for transport to the mill. Extractor fans in the combine separate leaf material from billets and deposit the plant residue on the soil surface. However, the mulch produced from the leaf material and plant residue is believed to promote disease and low yields in the next crop. As a result, burning the leaves off the whole stalks before harvest or burning of the residue on the soil surface after harvest are measures to reduce their impact on disease and/or possible yield reduction. Burning of the residue before or after harvest is a major environmental air pollution concern. Therefore, there is considerable interest in the impact of plant residue or mulch cover on weed controls, diseases, and insects. Numerous studies on several crops have shown that crop residue or surface mulch can enhance control of weeds and reduce herbicide loss. This information is essential for the implementation of control measures or corrective actions needed to reduce herbicide leaching and sediment losses from crop lands and thus reduce watershed's total maximum daily loads (TMDLs).

OBJECTIVES

Generation of a viable, effective management practice that prevents atrazine movement to groundwater and surface water is necessary. The combination of a management practice that protects water quality, avoids the burning of the combine harvester trash, and maintains the use of atrazine would be optimal. The specific objectives are:

- Compare the concentration of atrazine in surface water runoff from sugarcane grown under conventional sugarcane practices and best management practices (BMPs).

- Obtain quantifiable surface water data on the concentrations of atrazine and metribuzin present in surface runoff and the amounts remaining in the soil when the best management practices are

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used. This information will lead to understanding and implementation of corrective actions needed to reduce herbicide off-target movement from sugarcane fields.

- Make a recommendation on a BMP that is effective in significantly reducing atrazine runoff.

EXPERIMENTAL METHODS

The experimental site is located at the St. Gabriel Research Station of the Louisiana State University Agricultural Center. The experimental site was approximately 3.5 acres (1.5 ha), and the soil was classified as a commerce silt loam (Aeric Fluvaquent, fine-silty, mixed, nonacid, thermic). In 1997, the land was rowed and prepared for 6-foot rows (1.8 m spacing) where six plots (two replications x three treatments) running east to west were outlined with levees on each side of each treatment (see Figure 5). Recent planting of sugarcane variety CP70-321, a major variety for Southern Louisiana, was chosen, and planting was completed in September 1997.

At the lowest part (northeast corner) of each plot, we installed sumps (corrugated, galvanized culverts, 36 inches in diameter and 6 1/2 feet in depth (approximately 0.92 m I.D., and 2 m in length). A plate (sheet metal 1/16-inch thick) was welded at the bottom of each sump. A hole was dug and was subsequently back filled following installation of the sumps, and the remaining soil was used to close the levees surrounding each plot. Additional earth moving was carried out to ensure that each plot was completely leveed and that runoff water was collected into each sump through a V-type opening. In each sump, a water-pump connected to a flow meter was installed. As a result, the only outlet for surface runoff water was through the pump and flow meter and exiting into the levees between plots. Adjacent to each sump, we placed an ISCO water sampler and connected the sampler tubing and sensors to each sump by placing the sampler cup and a sensor at the bottom of each sump. Sample collection was triggered when the sensor placed in the sump detected runoff water.

For the preceding growing season, the sugarcane at the St Gabriel site was harvested on December 7, 1999. We harvested plots 1, 3, 5, and 6. Then we burned plots 2 and 4 with the sugarcane standing. Then we harvested plots 2 and 4. We measured the amount of mulch residue on the soil surface for all plots. No herbicides were applied or cultural operations carried out following harvest during the winter. During early spring (February 25, 2000), all plots were cultivated. This was carried out where all row middles were off-barred where top of the rows remained totally undisturbed.

Herbicide Applications

On April 7, 2000, all plots were sprayed according to the map below with metribuzin at the rate of 0.9 lb/acre of active ingredient on plots 3 and 5. All other plots received atrazine at the rate of 1 lb/acre of active ingredient. All herbicides were applied on a 36-inch band on top of the rows as described earlier. In addition, all plots received 2,4-D at the rate 1 quart/acre (active ingredient). Layby application was carried out on June 5 for all plots. This layby application consisted of broadcast atrazine application of 2 lb/acre (active ingredient) throughout the entire field.

RESULTS AND DISCUSSION

Runoff and Rainfall

During 2000 at the St. Gabriel site as well as south Louisiana, rainfall was considerably below of normal. This resulted in no runoff being collected during the 2000 growing season. The total rainfall (in inches) for 2000 was 40.48, 71% of normal and third driest year in history.

Surface Mulch versus Time

To assess the impact of the presence of a surface mulch residue on the retention of herbicides, the amount of mulch was measured. First, we measured the amount of mulch residue left on the field for each plot after harvest (December 7, 1999) using the combine harvester. Four plots were harvested, and the mulch was not removed. The other two plots were burned with the sugarcane standing before harvest. Four additional measurements were made during January, April and May, and August. Because of the disappearance/decay of the residue, no additional sampling was made thereafter. The average amount of mulch on the surface of the no-burn plots decreased continuously from a high of 8.04 ± 2.12 tons/acre on December 7, 1999, to a low of 1.66 ± 0.32 on August 18, 2000 (see Table 1). The mulch results are given in Figure 1 along with one standard deviation. It is of interest to point out that the measured amount of mulch during 1999 at another site south of Baton Rouge was well within that measured during 2000 as shown in Figure 1.

Weed Assessment

Weed assessment for all plots was carried out several times during the growing season before spring application of herbicides and following layby application. The following are notes from Dr. Griffin's visits.

Visual assessment of the experimental plots was made on the following dates: March 29, April 24, June 12, August 1, and August 30, 2000. At each of these dates, notes were made with regard to amount of mulch remaining on the row tops, weed control, and crop response.

March 29, 2000: In the burn plot treatments (plots # 2 and 4) there was very little mulch residue on the soil surface. Annual ryegrass, sow thistle, rescue grass, timothy grass, and Virginia pepper weed were present in significant quantity. This was in direct contrast with the other no-burn plot treatments (plots # 1, 3, 5, and 6), where mulch did an excellent job of suppressing weed growth. Cane plants were emerging in all plots at this rating. On April 7, plots were off-barred and sprayed according to the designated treatment. Additionally, 2,4-D was applied to the entire experimental area.

April 24, 2000: Winter broadleaf weeds, of which the predominant species was sow thistle, were controlled at least 95% by the 2,4-D application. Grass weeds were unaffected by the herbicide treatments. Timothy grass and rescue grass were naturally maturing with most plants dead. In contrast, annual ryegrass was headed and just at the flowering stage, but plants were still green. Cane was actively growing and not negatively affected by the herbicide treatments.

Cane mulch residue was visible on the surface of row tops and was continuing to suppress weed emergence.

June 12, 2000: Weed control in all plots was considered very good. Annual ryegrass had matured and dead plants were present. Cane had been worked (layby), was actively growing, and not negatively affected by the herbicide treatments. Cane shoot population did not seem to vary among the herbicide treatments.

August 1, 2000: It was difficult to denote much difference in regard to specific treatments. In all plots, weed control was considered very good. Annual ryegrass that had already died and dried up was still present in some plots. Very few weeds had emerged on the row tops or row middles since the cane had been cultivated at layby and treated with atrazine. There was some evidence of triazine injury on emerging morning glories. Based on visual observations alone, it is estimated that stalk populations in late August as well as cane yields were equivalent for all treatments (see separate section on yields and stock counts) section.

Overall Weed Evaluation

Weed control and sugarcane growth were not negatively affected by mulch present on the soil surface. Weeds were controlled with atrazine whether or not mulch was present. Avoidance of the off-barring tillage operation in the spring did not negatively affect the efficiency of cultivation or herbicide application at layby. As would be expected, sugarcane yields did not appear to be affected by either mulch management, tillage program, or herbicide application.

Previous research at the LSU AgCenter has shown that mulch distributed on the field during the combine harvesting operation can delay sugarcane emergence and growth in the spring but also can be positive in delaying weed emergence. A standard practice among growers is to remove the mulch from the row tops during the winter or early spring by burning or by mechanical removal. Another common practice is not to allow mulch to be deposited on the soil surface by burning the standing cane before harvest to remove extraneous leaf material. All of these methods accomplish the same goals of preventing mulch from interfering with cane growth in the following crop year and of preventing mulch from delaying the drying of fields and subsequent tillage operations in spring. Mulch cover during the winter, however, can be positive in helping to prevent freeze damage of sugarcane during severe winters and in reducing soil runoff losses.

From a practical viewpoint, unless there is a ban on burning, growers who harvest cane with combines will either burn the cane standing before harvest or come in after harvest during December or January and burn the mulch after it has dried. Burning standing cane can enhance sugar recovery by the mill. The possibility of the mulch cover delaying cane growth in spring is a major concern to growers. The benefits of the mulch in helping to minimize soil erosion and reduce pesticide movement from fields should be emphasized when considering changes in management programs.

Sugar Yield

A primary concern before recommendation of a new management practice is the effect on yield. In the 2000-growing season, the sugarcane was harvested on November 19 using a combine harvester. This was carried out in a similar manner as during the previous growing season. In addition, two weeks before harvest, the number of stalks per 100 ft of sugarcane rows (in triplicates) was recorded for all six plots (see Table 2). Moreover, subsamples of sugarcane stalks were taken to the laboratory for complete sugar analysis. The table below provides the results for all three treatments: no-burn metribuzin, no-burn atrazine, and burn atrazine. Bases on our analysis, no significant differences of sugar yields (tons per acre) were observed among all three treatments (see Table 3). In fact no single parameter indicated significant differences among all treatments. Such a finding is significant and illustrates the success of the use of alternative herbicides as a best management practice (BMP) for sugar. It is important to point out that sugar yields in all plots of the second replication (plots 4, 5, and 6), lower yields were observed. Such observation was perhaps caused by higher weed infestation in this part of the southern section of field at the St. Gabriel site.

CONCLUSIONS

Under conditions where mulch was not removed, it was concluded that there was no significant difference in sugar yield among the various treatments. Specifically, the use of band application of metribuzin for spring application provided equally good weed control in comparison atrazine and is thus recommended as an alternative pre-emergent herbicide for sugarcane in south Louisiana. Moreover, no significant differences of sugar yields (tons per acre) were observed among all three treatments. Such a finding is significant and illustrates the success of the use of surface mulch as well as metribuzin as an alternative herbicide as a best management practice (BMP) for sugarcane.

Table 1. Weight of sugarcane mulch residue in the various experimental plots (tons/acre), St. Gabriel, La., during the 2000 growing season.

	Date of measurement				
Plot*	12/17/1999	1/21/2000	4/6/2000	5/23/2000	8/18/2000
1	9.68	8.13	6.76	6.27	1.76
2	3.63**				
3	8.47	5.84	4.97	5.47	1.74
4	1.21**				
5	7.26	5.96	7.34	5.31	1.27
6	9.08	5.50	5.20	3.84	1.88
Overall Average	8.04	6.60	5.97	5.22	1.66
Standard Error	2.12	1.01	0.96	0.96	0.32

* Plots 1 & 6: No-burn, atrazine
Plots 2 & 4: Burn, atrazine
Plots 3 & 5: No-burn, metribuzin
** Not included in the overall average

Table 2. Stalk count (in triplicates) along a 100-feet long segment at St. Gabriel experimental site.

Number	Average	Replicate		
Plot Label	Stalk number	1	2	3
Plot 1	464	487	444	460
Plot 2	420	420	411	430
Plot 3	417	400	450	400
Plot 4	396	437	380	370
Plot 5	447	430	410	500
Plot 6	360	330	380	370

Table 3. Sugarcane yields for the different treatments during 2000.

TREATMENT	Rep. Number	Plot Number	Number of Stalk per acre	Cane Yield tons/acre	Total solids (BRIX) %	Sucrose %	Sugar Yield lbs/ acre
No Burn Metribuzin	1	3	30,300	31.0	15.5	12.7	5483
	2	5	32500	24.4	16.1	13.5	4654
	Average		31400	27.7	15.8	13.1	5069
No Burn Atrazine	1	1	33,700	34.7	15.2	12.4	5959
	2	6	26,100	17.3	15.7	13.2	3194
	Average		29,900	26.0	15.5	12.8	4577
Burn Atrazine	1	2	30,500	37.0	15.8	13.2	6840
	2	4	28,700	25.9	15.6	12.9	4655
	Average		29,600	31.5	15.7	13.1	5748
LSD 0.05			NS	NS	NS	NS	NS

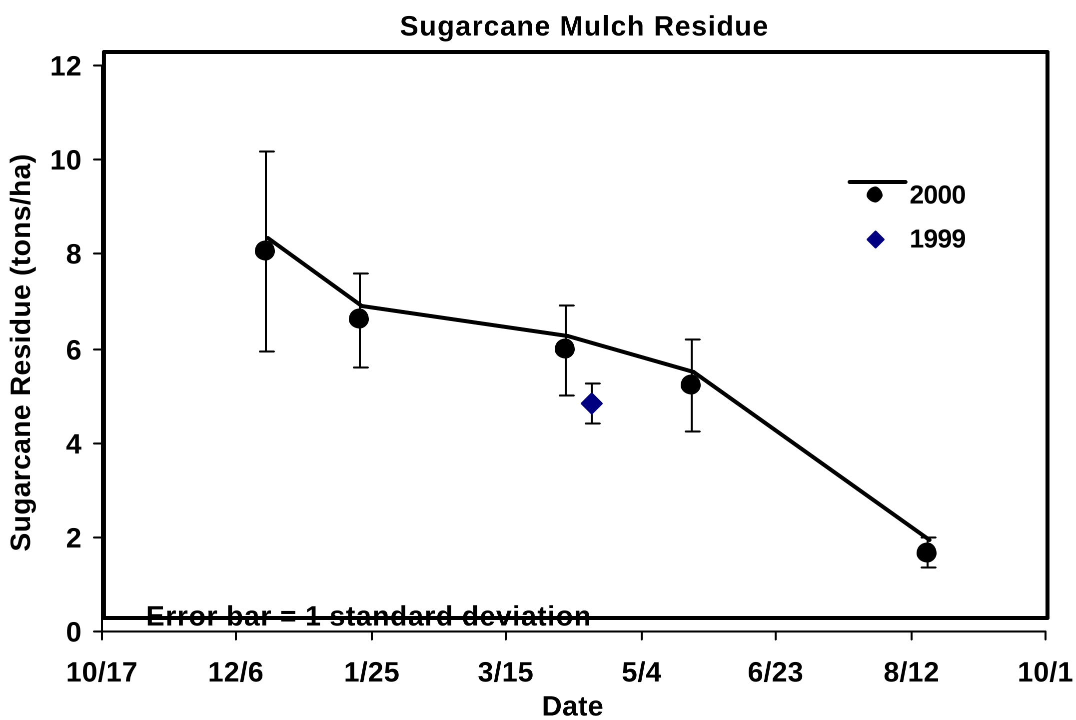

Figure 1. Amount of mulch residue remaining on the soil surface versus time during the growing season.

ATRAZINE ADSORPTION-DESORPTION BY SUGARCANE MULCH RESIDUE[2]

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INTRODUCTION

Various forms of soil conservation are highly recommended in continuing efforts to reduce soil losses and runoff of applied agricultural chemicals. Several conservation production systems are characterized by the presence of mulch residue left on the soil surface to protect it from water and soil erosion. In fact, numerous studies on best management practices have shown distinct advantages of minimum or no-till systems (Dao, 1991;1995, Banks and Robinson, 1982). However, we are not aware of published research that has been carried out on correlating the effectiveness of plant or mulch residue remaining on the soil surface, following sugarcane harvest, on the retention of applied herbicides, leaching losses in the runoff, and their downward movement in soil profile. We are also not aware of research efforts on the adsorption-desorption kinetics of herbicides such as atrazine or their fate during the crop's growing season as influenced by mulch residue over time following harvest. Such information is a prerequisite in quantifying the role of mulch residue in minimizing the leaching losses of applied agricultural chemicals.

MATERIAL AND METHODS

Bulk sample of sugarcane residue was collected from a private farm south of Baton Rouge on April 16, 1999, before application of herbicides. The residue was collected to quantify the adsorption-desorption behavior of sugarcane mulch for atrazine. The site was chosen to evaluate several BMPs, including mulch management practices, to determine their effect on herbicide retention and runoff losses. The soil was a Commerce silt loam soil (Aeric Fluvaquent, fine-silty, mixed, nonacid, thermic, and the sugarcane variety was LCP85-384. The mulch residue was dried at 55^0C for 24 hours and then cut into 1-cm sections (in length) and stored in a closed container before the experiments.

Atrazine adsorption-desorption by mulch residue was carried out using batch equilibration technique (Zhu and Selim, 2000). Radioactive atrazine was used as a tracer to monitor the extent of retention. Six ^{14}C-atrazine spikes having initial concentrations (C_i) of 3.37, 6.36, 12.34, 18.22, 24.30 and 30.16 μg mL^{-1} in distilled water were used. Adsorption was initiated by mixing 1 g of dried and cut sugarcane residue with 30 mL of the various atrazine concentration solutions in a 40-mL Teflon centrifuge tube. The mixtures were kept shaking and centrifuged at 500 $\times$ g for 10 minutes for each specific reaction time before sampling. A 0.5-mL aliquot was sampled from the supernatant at reaction times of 2, 8, 24, 48, 96, 192, 288 and 504 hours. The mixtures were returned to the shaker after each sampling. The collected samples were analyzed using liquid scintillation counting (LSC). Desorption commenced immediately after the last adsorption time step (504 hour). Each desorption step was conducted by replacing the

[2] This study was supported in part by a grant from Louisiana Department of Environmental Quality Non-Point Source Program (section 319), Jan Boydstun, project officer.

supernatant with atrazine free 0.005 M $CaCl_2$ solution and shaking for 24 hours. Six desorption steps were carried out with a total desorption time of six days. After the sixth step, one further extraction using a 4:1 methonal:water 0.005 M $CaCl_2$ solution was carried out.

RESULTS AND DISCUSSION

The amount of atrazine in soil solution versus that retained by the mulch residue is presented in Figure 1. These results are for the various reaction times used and are often referred to as adsorption or sorption isotherms. In most studies, isotherms based on 24-hour equilibration time are commonly accepted. Retention results for atrazine by the mulch residue were well described using a linear model. Specifically, for all reaction times of adsorption, the isotherms appear to be linear within the concentration range used. As a result, we obtained best-fit parameters values for the slope of the relationships shown in Figure 1, for each adsorption time. This slope is referred to as the distribution coefficient (K_d) and represents the partitioning between the amount of atrazine in the solution phase and that retained by the solid phase (see Ma and Selim, 1997).

The K_d values, which represent the affinity or strength of adsorption by the mulch residue, exhibited a gradual increase with the time for reaction from 16.4 to 23.40 cm^3/g after 24 and 504 h, respectively (see Table 1). These results are indicative of strong kinetic behavior of atrazine adsorption by the mulch residue. The change of K_d values for the mulch residue versus time is shown in Figure 2. Such kinetic behavior also is manifested by the change in concentration versus time during adsorption by the mulch residue for the wide range of concentrations used shown in Figure 3. It is clear following the initial decrease in concentration, a gradual decrease with time was observed for the entire range. This data, when expressed in terms of the amount adsorbed versus time, clearly illustrates the kinetic of the retention mechanisms by the mulch residue (see Figure 4). The continued but slow increase of the amount sorbed is indicative of a kinetic reversible as well as irreversible reactions. Such kinetic retention also is depicted by the adsorption isotherms for the different retention times.

Values for mulch residue K_d were an order of magnitude higher than that found for the soil matrix of Commerce soil. This was expected since organic matter is the principal soil component affecting the adsorption of many herbicides in the soil environment. These results are clearly illustrated when we compare our adsorption isotherms for the soil matrix given in Figure 5 with that for the mulch residue of Figure 1 to compare the extent of retention by the soil matrix. Specifically, the K_d values for the soil matrix were obtained (see Table 2). These values ranged from 2.095 to 2.352 cm^3/g after 24 and 384 h of reaction time, respectively. Moreover, the K_d values for the soil matrix exhibited limited kinetic behavior of atrazine as shown in Figure 6. In contrast extensive kinetics were observed for the mulch residue (Figure 2). Therefore, we conclude that results from our laboratory study of the retention kinetics of the mulch residue were consistent with field measurements. A distribution coefficient (K_d) for mulch residue (23.40 cm^3/g) was an order of magnitude higher than for the Commerce soil (2.352 cm^3/g).

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Table 1. Goodness of fit of the linear model for the different retetntion time for atrazine adsorption and desorption by the sugarcane mulch residue.

	Time (hours)	Kd (mL/g)	r^2
Adsorption	2	10.40±0.1619	0.996
	8	14.27±0.1399	0.998
	24	16.40±0.1597	0.998
	48	17.22±0.1596	0.997
	96	17.58±0.1540	0.998
	192	19.43±0.1949	0.998
	288	20.37±0.1836	0.998
	504	23.40±0.2398	0.998
Desorption	528	40.47±0.4960	0.998
	552	72.54±1.0380	0.996
	576	124.67±2.4870	0.993
	600	215.20±4.6560	0.992
	624	345.20±8.5260	0.989
	648	505.30±4.6160	0.986

Table 2. Goodness of fit of the linear model for the different retetntion time for atrazine adsorption and desorption by the Commerce soil.

	Time (hrs)	Kd, (mL/g)	Standard error (mg/L)	r^2
Adsorption	2	1.843	0.04325	0.9973
	6	1.972	0.05716	0.9958
	12	2.073	0.04707	0.9974
	24	2.095	0.0492	0.9973
	48	2.055	0.05692	0.9962
	96	2.328	0.07493	0.9948
	192	2.248	0.08431	0.993
Desorption	384	2.352	0.09246	0.9923
	408	4.856	0.2145	0.9903
	432	10.004	0.4585	0.9896
	456	19.768	0.8398	0.9911
	480	34.506	1.3956	0.9919
	504	57.807	2.6203	0.9898
	528	91.756	2.9795	0.9948

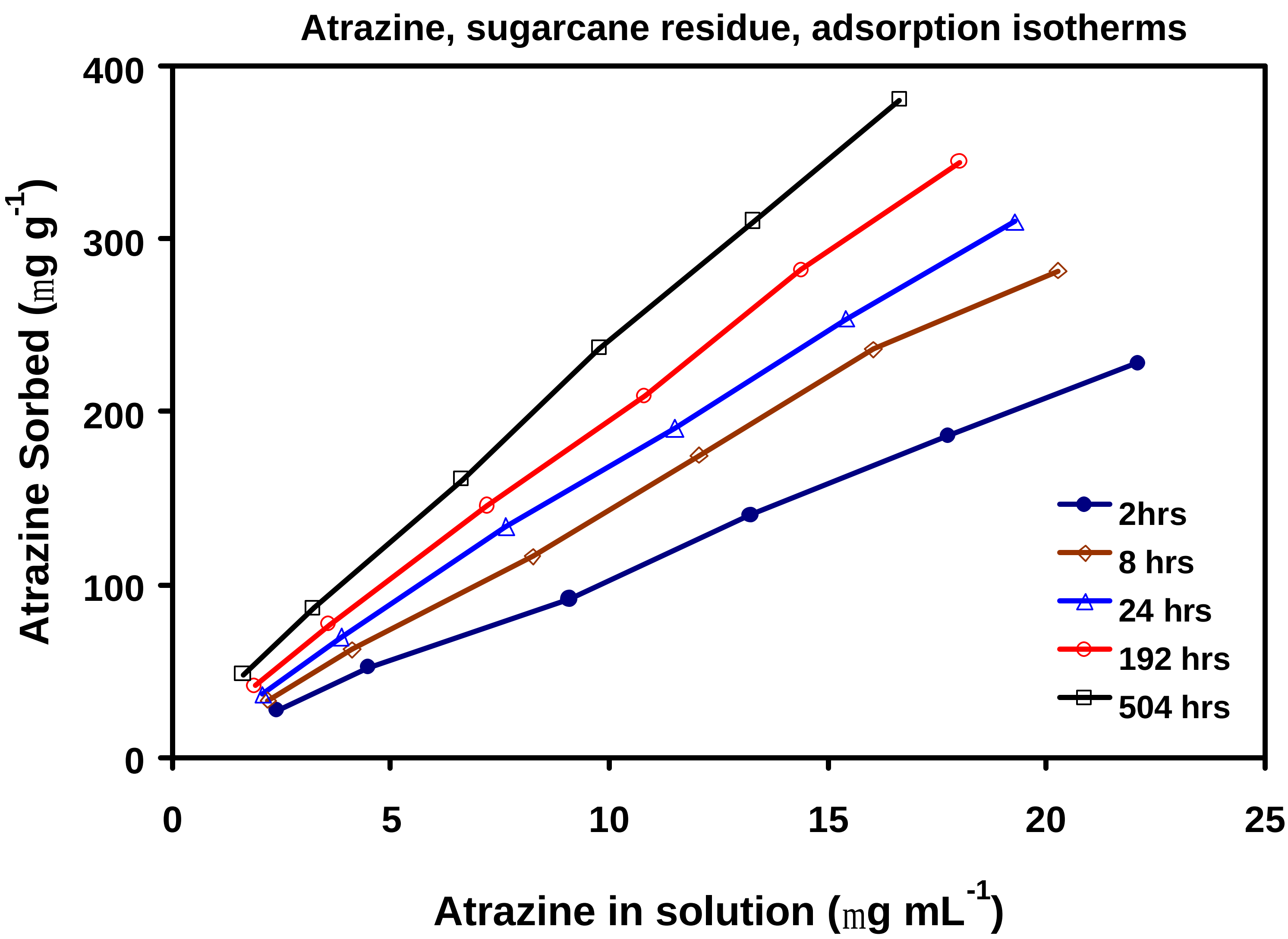

Figure 1. Atrazine adsorption isotherms for sugarcane mulch residue as a function of retention time.

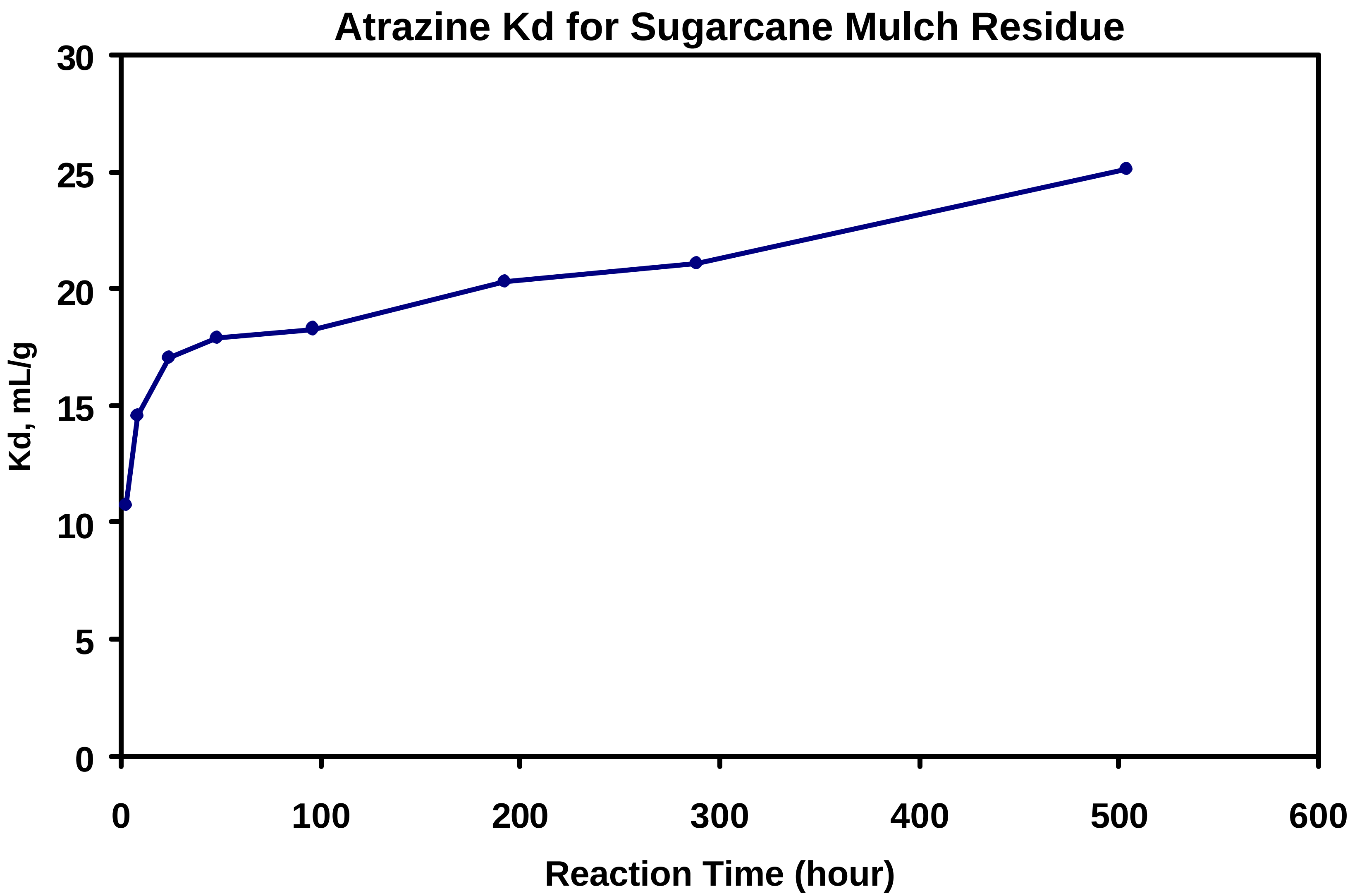

Figure 2. Measured atrazine distribution coefficient (Kd) versus reaction time for sugarcane mulch residue.

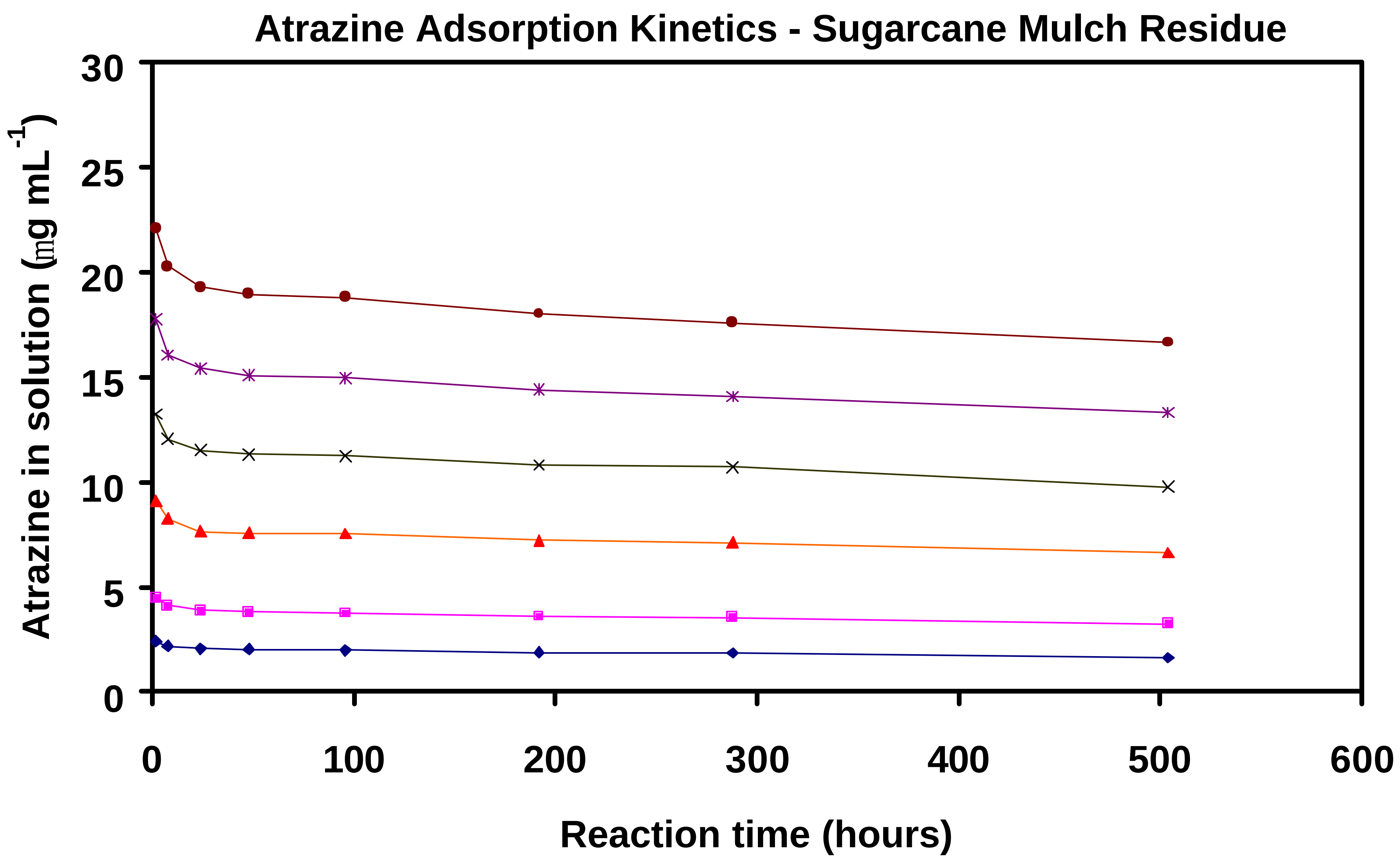

Figure 3. Measured atrazine concentration versus reaction time for different initial concentration (C_I) for sugarcane.

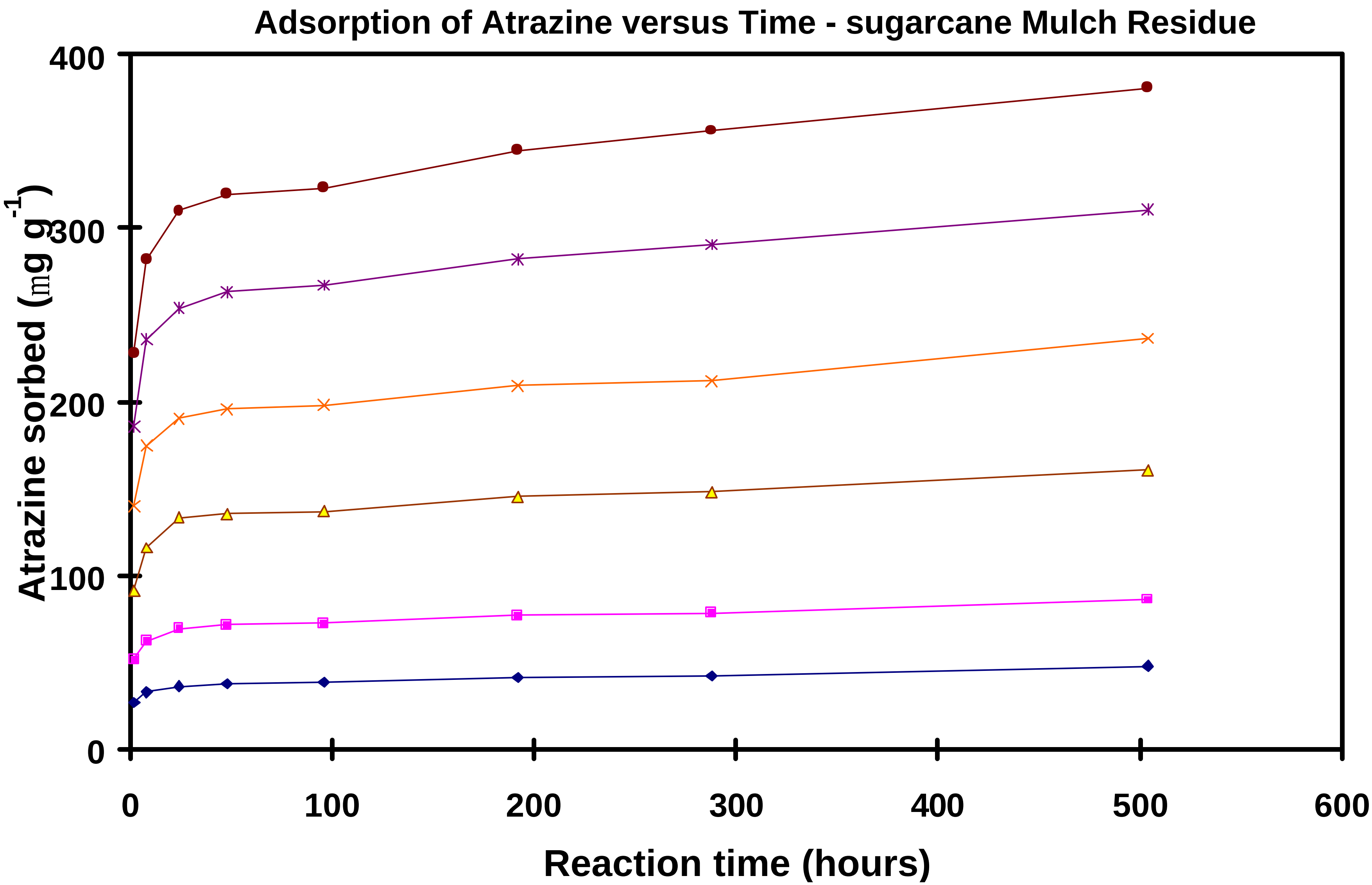

Figure 4. Measured sorbed concentration of atrazine versus reaction time for different initial concentration (C_I) for sugarcane mulch residue.

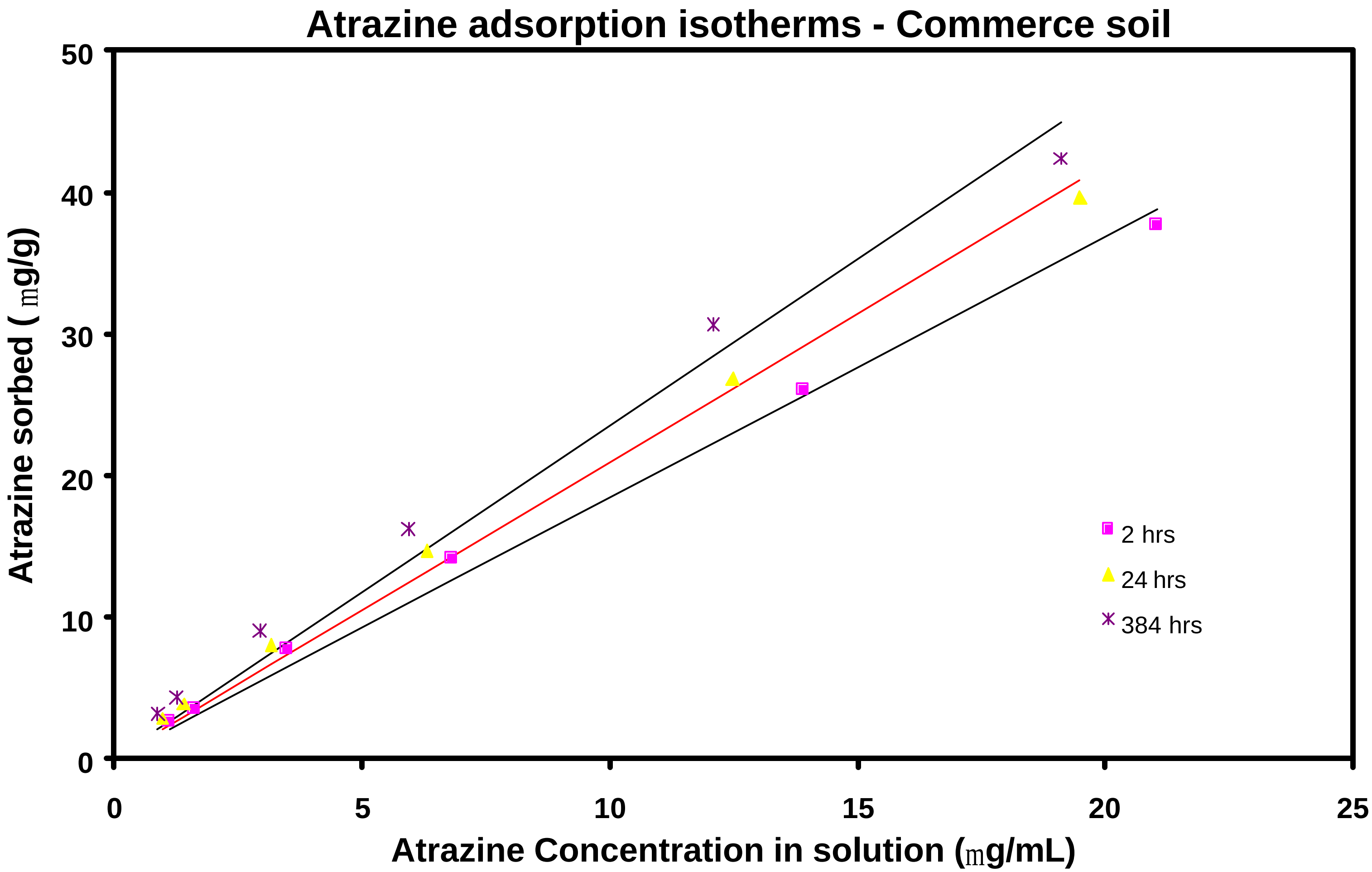

Figure 5. Atrazine adsorption isotherms at different reaction time for Commerce silt loam soil. Solid lines are the predictions using a linear model.

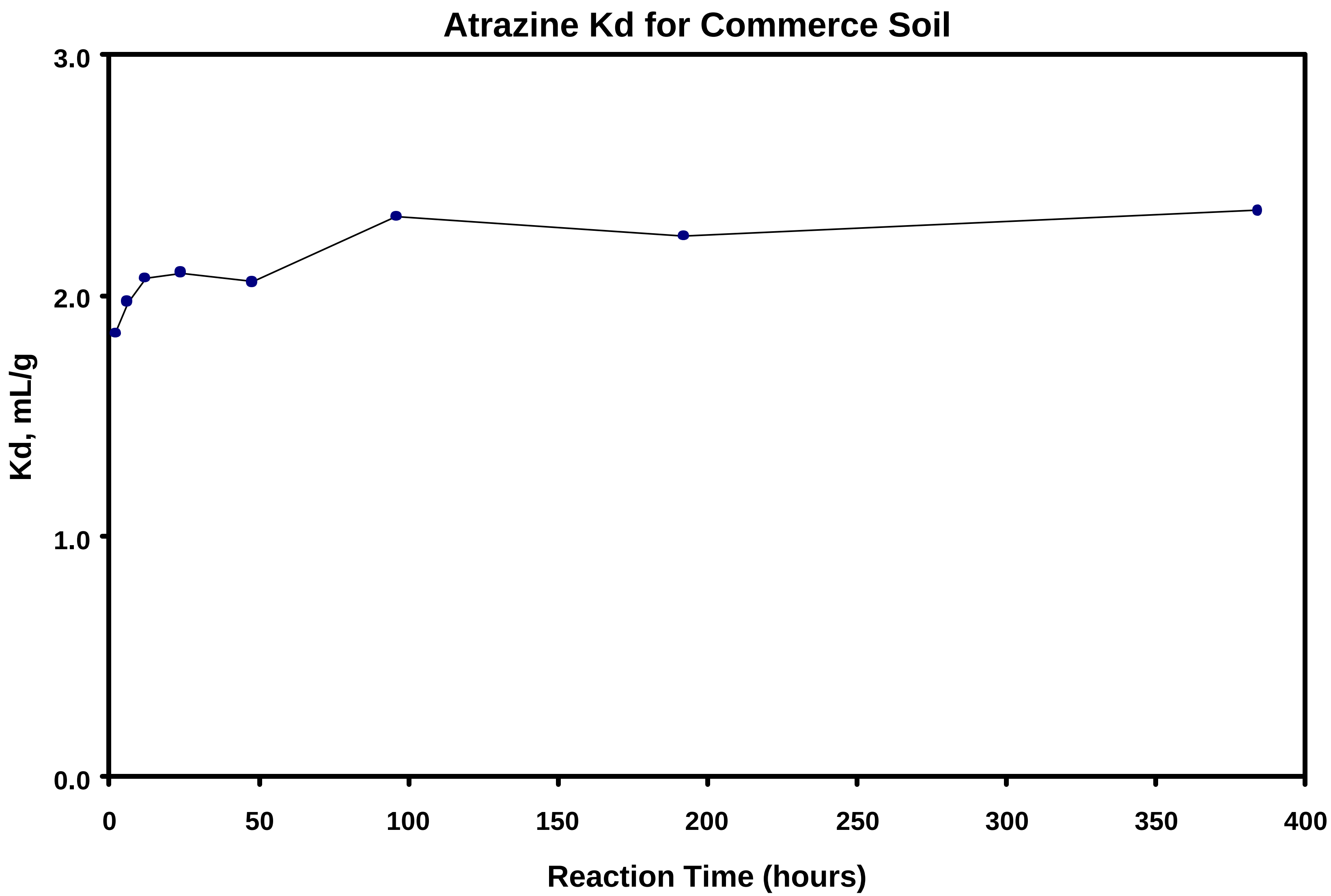

Figure 6. Measured atrazine distribution coefficient (Kd) versus reaction time for Commerce silt loam soil.