

Simazine Mineralization in Wetland Soils of William's Island

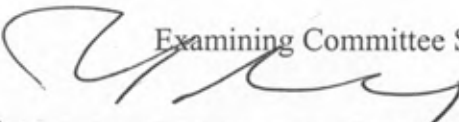
by  
Elise Chapman

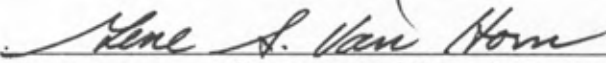
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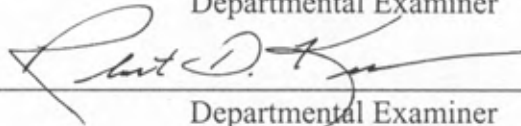
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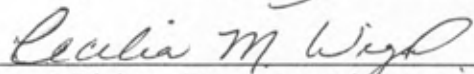
Committee Members:  
Dr. Gene Van Horn  
Dr. Robert Keller  
Dr. Cecelia Wigal

Examining Committee Signatures:

  
\_\_\_\_\_  
Project Director

  
\_\_\_\_\_  
Departmental Examiner

  
\_\_\_\_\_  
Departmental Examiner

  
\_\_\_\_\_  
Liaison, Departmental Honors Committee

  
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Chairperson, University Departmental Honors Committee

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**ABSTRACT:**

Wetlands are an interface between terrestrial and aquatic environments. As anthropogenic impacts on the environment increase it puts these sensitive areas at the forefront of change. Farming on William's Island has not occurred since 2001 but before that it was farmed to provide cost-free upkeep of the island. Simazine is a triazine herbicide, the most commonly used group of herbicides in modern agricultural practices. The fields on William's Island were most likely exposed because they were farmed for numerous years prior to 2001. Because of this the wetland that drains the fields, separating them from the Tennessee River, may have been previously exposed and if this is true the wetland would be able to function as an improved degrader of herbicides. Three sites across the wetland were examined, and three cores taken at each site. Microcosms of the soil were created and inoculated with both C<sup>14</sup> Simazine and C<sup>12</sup> Simazine. The NaOH, which captured radiolabeled CO<sub>2</sub>, was sampled from the microcosm set-ups first after roughly 24 hours and subsequently every three days until five samplings were taken, with a sixth sampling a month after the start of the incubations. The radiolabeled CO<sub>2</sub> was then counted in a scintillation counter. From the data a mean maximum rate of degradation for each site was calculated. Site A had a rate of 8.91 +/- 0.96 ng Simazine/g wet soil/hour at 25° C incubation; site B had a rate of 8.14 +/- 0.28 ng Simazine/g wet soil/hour at 25° C incubation; site C had a rate of 9.07 +/- 1.38 ng Simazine/g wet soil/hour at 25° C incubation. There was no statistical difference between the mean maximum rates of the three sites according to the ANOVA test run on Minitab. Site A had a rate of 2.61 +/- 1.07 ng Simazine/g wet soil/hour at 8° C incubation; site B had a rate of 2.61 +/- 1.07 ng Simazine/g wet soil/hour at 8° C incubation; site C had a rate of 1.86 +/- 0.41 ng Simazine/g wet soil/hour at 8° C incubation. Again, there was no statistical difference between the three sites according to the ANOVA test on Minitab. Although, there was no statistical difference between the three sites within the same temperature incubations, there was obvious difference between the rates at the two temperature incubations. These rates indicate that the wetland does filter Simazine before it contacts the Tennessee River. This happens at a greater rate at higher temperatures, which occur during the season when application takes place and the wetland would have larger amounts of herbicides. Comparison between the rates of degradation in this study and those done on a pristine site indicate substantially increased rates at sites of prior exposure (between 13 and 65 percent higher), corroborating past findings of other research. Although not statistically different there was slightly higher rate of degradation at site B, most likely because it has the most stable saturation throughout the year. More importantly, these rates of degradation indicate that the turnover time of these herbicides in cooler temperatures is slow, meaning that applications of Simazine during seasonal cold periods will have a greater effect on the environment because their degradation takes much longer than during seasonally warm periods.

## **INTRODUCTION:**

Chemicals find their way into water supplies through numerous avenues and from countless sources. Agriculture is a major contributor of these chemicals for the better part of the Mississippi River drainage basin, so it is vital that in this part of the country we include quality with respect to the absence of these chemicals as a fundamental parameter in evaluating water resources (Hirsch, Miller, & Hamilton, 2001). From numerous avenues agricultural chemicals eventually reside in surface waters (Pereira & Rostad, 1990), and since the Mississippi River drains most of the crop land of North America it is a major contributor to pollution in the Gulf of Mexico.

William's Island is located in the Tennessee River in Nickajack Reservoir, across from the Baylor School in Chattanooga. The island is fielded and has had human presence manifested in agriculture documented as early as 10,000 years ago. This study was done on a wetland on William's Island, which empties into the Tennessee River. Almost half the water exiting the Mississippi River comes from its tributary the Ohio River (Pereira & Rostad, 1990), and the Tennessee River feeds the Ohio just shortly before it joins the Mississippi. Not only herbicides but also their degradation products are sources of non-point source pollutants at the mouth of the Mississippi (Pereira & Rostad, 1990). While it is not immediately evident, because of low concentrations and time sensitive discharge, herbicides are a substantial component of this contamination as a result of their accumulation (Clark, Goolsby, & Battaglin, 1999). For this and more local agricultural monitoring reasons it is

important to investigate the degradation of such chemicals in water drainage systems, specifically wetlands because of their longer water retention times. Sorption to soil particles and or plant matter and degradation are the most common processes that manipulate the movement of herbicides in the soil (6). Degradation of herbicides is attributed to many microorganisms that reside in wetlands and so not only do they serve to hold the contaminated water they seem to provide some mitigation before they discharge into larger bodies of water.

Non-point sources of pollution are currently blamed for many water quality problems, and they are difficult to address because of their complexity (Hirsch, Miller, & Hamilton, 2001). These chemicals in water have countless detrimental effects. Life forms from insects to many amphibians have embryos that mature in the aquatic environment and chemicals have a distinct injurious effect on their development. Exposure to atrazine, another triazine herbicide closely related to Simazine, causes male frogs to become hermaphroditic by disturbing hormonal indicators as well as causing naturally hermaphroditic fishes to become female (Ralloff, 2002). Even contact with trace amounts of atrazine, as low as 0.1 parts per billion (rainwater can contain as much as 0.4ppb), has been shown to instigate emasculation of male frogs (Ralloff, 2002). There is little known about the effects of long term exposure to these chemicals on humans. Wetlands serve to initially process these chemicals before they reach the groundwater, which is often the source of domestic drinking water.

In the United States a huge portion of land within the Mississippi River drainage basin is devoted to agriculture, which at one time had numerous wetlands covering a large surface area (Moore et al., 2001). As transition zones between terrestrial and aquatic environments these wetlands served as buffers between agricultural fields and streams until they were drained. This is not without negative effects on the environment. As the wetland is required to deal with large amounts of agro-chemicals it begins to change (DeLaney, 1995). Also, as demands on resources increase the wetlands are drained to provide arable land as well as suitable sites for housing (Reddy & Gale, 1994). Because of their limited numbers and vast functions, natural wetlands should not be used to mitigate agricultural runoff (Hammer, 1993). The wetland on William's Island is a natural wetland and was not intentionally used to filter the herbicides, but is a part of the natural drainage system of the island. As such it functioned to alter the direct movement of herbicides into the Tennessee River. It has been farmed for many years and there is evidence supporting the presence of human agricultural activities dating as far back as 10,000 years.

Simazine is a triazine herbicide that is used extensively in farming many crops to control grassy and broadleaf weeds (Scribner et al., 1992). Although it has a low water solubility (Worthing & Hance, 1991), it is seen as a noteworthy non-point source pollutant of waters (Agbekodo, Legube, & Dard, 1996; Templeton, Zilberman, & Yoo, 1998; Wauchope, 1978). Triazine herbicides, mostly Atrazine and Simazine, have been limited to certain crops and at levels not above 1.5kg per ha. Even in light of this, triazine herbicides are a source of concern because of their persistence

(Comber, 1999). Simazine is an extensively used herbicide and William's Island was farmed with conventional modern tillage methods so it was most likely exposed to Simazine or other triazine herbicides. It is known that in the past two years the wetland has not been exposed to herbicides, since farming of the fields has ceased.

Wetlands serve as excellent buffers between aquatic and terrestrial environments but with increased stress they change, as any dynamic natural system will (DeLaney, 1995). Further investigation is necessary in the area of wetland performance and utility. The wetland on William's Island, as a natural wetland, is not specifically designed to treat agricultural runoff. However, with prior exposure it has been seen that soils contain microbes that act to quickly degrade herbicides, which could be the case with the wetland on William's Island. Understanding the rate of herbicide degradation is important because degradation and sorption are the main principles influencing herbicide movement in soil and water systems (Garcia-Valcarcel & Tadeo 1999).

Although little is known about herbicide behavior and movement in natural wetlands, beyond the fact that wetlands can serve to mitigate herbicides, constructed treatment wetlands are well monitored and easily studied. Since so many acres of wetlands in agricultural areas have been drained and converted to arable or habitable land there has been an increase in the assembly of constructed wetlands. These wetlands seek to return at least some fraction of the benefits wetlands present. These constructed treatment wetlands have provided insight into the complex processes of degradation and sorption as a result of the necessarily close monitoring. This

monitoring is, however, a large part of the impracticality of these engineered “natural” systems. If a wetland was constructed for the sole purpose of managing pollutants, herbicides specifically, it may fulfill that restricted function. It is vital to keep in mind that even well managed constructed wetlands are not a universal remedy for non-point source pollutants and need to be used simultaneously with environmentally sound crop management (DeLaney, 1995). The best approach would be to allow the natural watershed to reclaim the wetlands that once existed and to leave the current natural wetlands and allow them to function as wetlands have in the past to mitigate a substantial amount of necessary runoff.

The Tennessee River Gorge Trust has managed William’s Island since the late 1980’s and it continually seeks knowledge of the lands it strives to protect. The information gained in this study will not only aid the Trust in their management efforts but also has broader application in areas of agricultural management.

#### **METHODOLOGY:**

In Field: Collecting was done in a wetland on the west side of William’s Island in the Tennessee River on the Nickajack Reservoir (see Fig.1). Collection of sediment samples was done on December 18, 2002 using cores 5.5 cm in diameter. The sediment was then stored in labeled zip lock bags. It was a sunny day with mild winds, following a good period of rain (although the area had been in an overall drought for five years). The wetland had approximately 2 feet of standing water at the sampling sites. Three samples were taken at each of three sites along a transect of the wetland as indicated on the attached map (Figure 1). From a point of reference

the directionality of the transect was noted along which the sites were labeled, their GPS position recorded (see Table 1), and the core samples extracted. At the same time field temperature readings were recorded and surface water was collected. All of the samples were placed into a cooler until they were taken to the lab.

In Lab: Most of the work was done in microbiology labs at the University of Tennessee at Chattanooga. Swamp surface water collected from the sample site was immediately filtered upon return to the lab in order to have sufficient amounts of filtered surface water to prepare slurries. The top 1-cm from the sediment core samples the top was removed using a clean spatula. Previous studies have shown that Simazine and other triazine herbicides do not exhibit high levels of leaching so it is best to sample upper portions of the soil (Scribner et al., 1992). From the cores' top 1 cm a 2-cc substrate sample was put into a pre-weighed drying pan and placed in the drying oven for at least 72 hours and then weighed to determine the sediment water content. A 1-cc substrate sample of the core's top 1 cm was placed in a flask for slurry production. 100-mL of filtered surface water (collected from the swamp) was added to the flask with the 1-cc sediment sample, and was stirred with a magnetic stir bar until homogenized. From the slurry 10-mL was put into a pre-weighed pan and placed in the drying oven for at least 72 hours and then weighed, 10-mL after mixing thoroughly was used to measure the pH, and four microcosms received 20-mL each of the slurry. Herbicide mineralization studies in microcosms were then initiated with  $C^{12}$  Simazine and  $C^{14}$  Simazine additions. The  $C^{12}$  Simazine was added to reach a concentration of 1 ppm in the microcosm, which is the amount commonly found in

surface water runoff from recently treated cropland. After the herbicide was added the microcosms were sealed with a butyl rubber stopper assembly complete with 3-mL test tube for the 2-cc of 1 Normal NaOH and 5-cc plastic syringe, all secured by a rubber band (see Figure 2). The microcosms were gently agitated for one minute and left to incubate. The microcosms were divided into two groups, one incubated at room temperature (25° C) and the other incubated at field temperature (8° C). This process was repeated for all nine of the core samples collected in the field.

Once the microcosms had incubated for roughly 24 hours mineralization sampling began. Exact times of samplings were noted for calculating actual incubation times. Before each sampling replacement syringes were prepared with 2-cc of 1N NaOH and labeled scintillation vials were laid out to allow for efficient sampling. Sampling a microcosm consisted of extracting the 2-cc of 1 N NaOH using the syringe sealing the microcosm and immediately replacing it with a fresh NaOH. The replacement syringe was used to inject the fresh 2-cc of 1 N NaOH into the suspended test tube, and the microcosm was agitated in order for the slurry to be mixed. 1-cc of the then recovered 1 N NaOH was put into one of the scintillation vials and closed while the remainder was expelled into a waste container. The same setup was repeated for all 36 of the microcosms. This process was repeated at each of the time points noted in the raw data table (Table 2) to yield a time course of the Simazine mineralized.

The scintillation vials were prepared for counting by adding a scintillation cocktail (Packard Optisafe) to the vials and then thoroughly mixing them. The vials,

samples, and cocktail were then placed in the scintillation counter. The machine generates data in a form conducive to creating a spread sheet. The data were then more easily analyzed. Finally, Minitab was used to run a statistical analysis on the data, an ANOVA test with Tukey interpretation was performed.

## **RESULTS:**

Original data from the scintillation counter is found in Table 2. It is important to note that during the entire course of the experiment the highest percentage of Simazine mineralized was 2.71%, which is more than sufficiently low to ensure that it was not limiting to the microbes in the microcosms during incubation. Table 3 consists of the series of calculations done to arrive at the mean maximum rates for both the high (25° C) and low (8° C) temperature incubations. The high temperature incubations from site A had a mean maximum rate of degradation of 8.91 +/- 0.96 ng of Simazine/g wet soil/hour. Site B had a mean maximum rate of degradation of 8.14 +/- 0.28 ng of Simazine/g wet soil/hour, and site C 9.07 +/- 1.38 ng of Simazine/g wet soil/hour. In the low temperature incubations site A had a mean maximum rate of degradation of 2.61 +/- 1.07 ng of Simazine/g wet soil/hour, site B 3.47 +/- 0.67 ng of Simazine/g wet soil/hour, and site C 1.86 +/- 0.41 ng of Simazine/g wet soil/hour.

Figure 3 illustrates the varying rates between the high and low temperature incubations along with their standard error. It shows that there was at least a two-fold increase in the rate of mineralization from the low temperature to the high temperature incubations. Not only was this seen in the mean maximum rates but also in the time course of mineralization. Figure 4 shows that during the entire time

course of sampling the amount of Simazine mineralized was lower at each time interval for the low temperature incubations than in the high temperature incubations. This figure also makes it evident that the high temperature and low temperature incubations exhibited very different rate curves over the time course. Low temperature incubations showed the greatest rates of mineralization later in the sampling while initial rates of the high temperature incubations began more steeply and tapered off toward the end of sampling.

Statistical analysis done with Minitab showed that at a 95% confidence level sites A, B, or C were statistically similar to each other at low temperature incubations ( $P = 0.514$ ). Sites A, B, or C were also statistically similar ( $P = 0.848$ ) at high temperature incubation. Table 4 illustrates the ANOVA test run on Minitab software and its Tukey interpretation for both the high and low temperature incubations. Figure 5 illustrates the averages and the standard deviation box plot created in Minitab for the low temperature incubations. It is interesting to note that the mean rates of sites A and C come very close to being statistically different from site B. Figure 6 illustrates the averages and the standard deviation box plot created in Minitab for the high temperature incubations. The difference between the high and low temperature incubations was clearly significant.

## **DISCUSSION:**

It is evident that the high temperature ( $25^{\circ}\text{C}$ ) incubations have a higher rate of degradation compared with those incubated at field temperature, which was  $8^{\circ}\text{C}$ . This is to be expected since biological processes, including microbial degradation,

increase with temperature up to a maximum temperature. This suggests that in warm seasons the wetland will be more able to cope with herbicide runoff by degrading it, but as a natural system there are numerous other variables to be considered (Cole, 1998).

There was an almost five-fold increase in maximum rate of mineralization between the low and high temperature incubation means in soils from site C. In site A there was a three and a half fold increase between incubations and the rate more than doubled for site B's high temperature incubation. This difference in rate for all the sites may possibly be explained by the increase in activity of the degraders as well as a possible increase in their population size at higher temperatures.

The low temperature incubations not only showed differences with respect to maximum rates of degradation but also in the time course of their activity. High rates of degradation soon after sampling were seen in the high temperature incubations, this is important for the wetland to serve as a filter because old Simazine becomes unavailable for degradation possibly due its binding to soil and subsequent slow desorption (Scribner et al., 1992). Field temperature incubations took some time to increase the rate of degradation but did reach substantial rates toward the end of the experiment. Since cold seasons are not usually planting seasons these decreased levels of degradation would not be decidedly influential to the wetland's performance in filtering herbicides. The high temperature incubation sites show the characteristic logarithmic curve that is associated with degradation rates. The low temperature incubations, however, showed a gradual initial increase before tapering off at the end

of sampling. This caused the maximum rates of degradation for the low temperature incubations to occur at a later time interval.

Soils at all of the sites were sufficiently saturated with water; that was good since previous studies all agreed that moisture content positively influenced the rate of degradation (Garcia-Valcarcel & Taldeo, 1999; Walker & Blacklow, 1994). The low temperature incubations show that sites A and C have slightly lower rates of degradation than site B (not statistically different). Although the wetland did have standing water during the sampling time, it was at the beginning of the rainy season. The wetland does dry out in the summer months when rain is not abundant and temperatures are high. This alternating cycle of water level is not conducive to bacterial activity in soil. Studies have shown that such cycles are detrimental to degradation rates of herbicides (Garcia-Valcarcel & Tadeo, 1999). One reason for this decreased ability to degrade herbicides stems from the sorption of the herbicide (Garcia-Valcarcel & Tadeo, 1999). Of the C<sup>14</sup> Simazine added to the microcosms the most recovered in radiolabeled CO<sub>2</sub> was 2-3% so the remaining may have been sorbed into the sediment of the microcosm. Site B was located in the center of the wetland while sites A and C were on the periphery. Sites A and C have slightly depressed rates of degradation (although not statistically different) compared to site B. This finding suggests that the center of the wetland experiences the greatest stability in water levels over the year. This would provide better conditions for degradation because of decreased sorption and healthier populations of microorganisms that carry out mineralization.

Although the high temperature data shows a slightly depressed rate of degradation in site B there are many reasons that this could occur. Since field temperature was 8° C, much lower than the 25° C incubation, the organisms in the microcosms may have undergone any number of changes. Varying natural conditions once in the lab will most definitely alter the activity of the organisms. In this study it could very well have changed something that resulted in equalizing the different sampling sites' rates of degradation, which in turn, means it may be difficult to make any conclusions about the difference in the activity within the wetland without sampling during the time period discussed.

Prior exposure to herbicides has been shown to increase rates of degradation (Garcia-Valarcel & Tadeo 1999; Rouchaud et al., 2000; Walker & Jurando-Exposito, 1998). We were unable to sample a pristine site to determine if these rates are elevated from an area lacking prior exposure but it is obvious that the William's Island wetland soil did have high rates of degradation in all three sites. A study done by other University of Tennessee at Chattanooga students on herbicide degradation in a pristine site shows rates of 1.38E-9 mg/mL/hr. (Alexander et al., 2002). By assuming that 1mL water is equal to 1g the rates can be compared to the rates obtained from the William's Island study. Soils in the wetland in William's Island with a rate of degradation of 8 ng Simazine/g wet soil/hour is approximately 6,150,000 times greater than that of the spring water site representing a "pristine" site. This seems to substantiate that there was prior exposure to the soil in the William's

Island wetland and that the microbial community has developed and maintained a propensity for mitigating the presence of herbicides through degradation.

The presence of this type of microbial community is indicative of a working wetland that filters at least some of the herbicides that enter it and in this case prevent them from reaching the ground water or the Tennessee River. This positive aspect of the wetland's function is not without several aspects that must be examined; although it is environmentally positive that a herbicide is degraded and prevented from contaminating other environments or accumulating, it decreases its effectiveness making it necessary to apply larger amounts to crops or fields (Rouchaud et al., 2000). Accelerated degradation is limited by varied agricultural practices, such as crop rotation.

Turnover time is a commonly used expression of herbicide behavior that is valuable to agriculturists as well as those who study herbicide movement in ecosystems. The maximum allowable level of application of Simazine that could be applied to the approximately 117 acre area that drains into the wetland is 70.49 kg Simazine. If all of the applied Simazine were to make its way into the wetland, the time it would take microbes in the 24.5 acre wetland to degrade half of that Simazine at the minimum mean rate observed for the low temperature (8° C) incubations would be close to 1,469 days. However, the wetland does not remain that temperature. At the maximum mean rate of mineralization in the 25° C incubations it would take the wetland about 164 days to degrade half of that application of Simazine. Actually during many of the summer months the sediment temperature will be higher than 25°

C yielding even higher rates of degradation. Caution must be exercised in making any concrete conclusions about a natural system. In the summer months, for example, precipitation is often lower than in the months of sampling, which would decrease the working surface area of the wetland. This decrease in area available for microbial activity increases the turnover time of the wetland. Still, turn over times in the hundreds of days show that William's Island natural wetland would successfully mitigate herbicides washed into it during times of agricultural use of the island's fields. Herbicides need to remain intact and active in order for them to achieve their intended purpose. Degradation prevents the herbicide from being effective, so a fine line lies between prevention of pollutants migrating to water systems and controlling competition of weeds against crops. Wetland alleviation of herbicide pollutants is ideal in that it diminishes the herbicides once they have washed from the cropland, not preventing them from achieving their designed purpose.

#### **CONCLUSIONS & RECOMMENDATIONS:**

From the results of this experiment, it can be concluded that the wetland on William's Island has served to mitigate the herbicide runoff from the fields on the island that were farmed. Furthermore, because of its prior exposure it can serve in greater capacity to do so should the occasion arise in the future. It can also be said that, although treatment wetlands have been the chosen option for bioremediation of agrochemical runoff in many areas, the ability of natural wetlands to do the same is evident. In the absence of the destruction of natural wetlands there would be no need

to create treatment systems, which require constant monitoring and large upfront expenses of engineering and construction.

The data shows that the higher incubations had higher maximum rates of degradation. It would be interesting to see data from a study done in a different season and then compared to this data, which was obtained from a field temperature of 8° C. Since there was very little difference in the three sites at high temperature incubations, it would be interesting to see if the same held true when the field conditions were seasonably warmer. It may be that a difference similar to this study's low temperature incubations (i.e. Site B having a slightly elevated mean maximum rate of degradation) would be seen. On the other hand, because of the possibility of a completely different microbial makeup in a different season there may be very different relationships visible between the three sites. In addition, a site that is thought to be "pristine" is located near the Pot House and is open to being sampled. Sampling done on both that "pristine" site and the William's Island wetland site concurrently would yield a better comparison of maximum mean rates of degradation.

#### **ACKNOWLEDGEMENTS:**

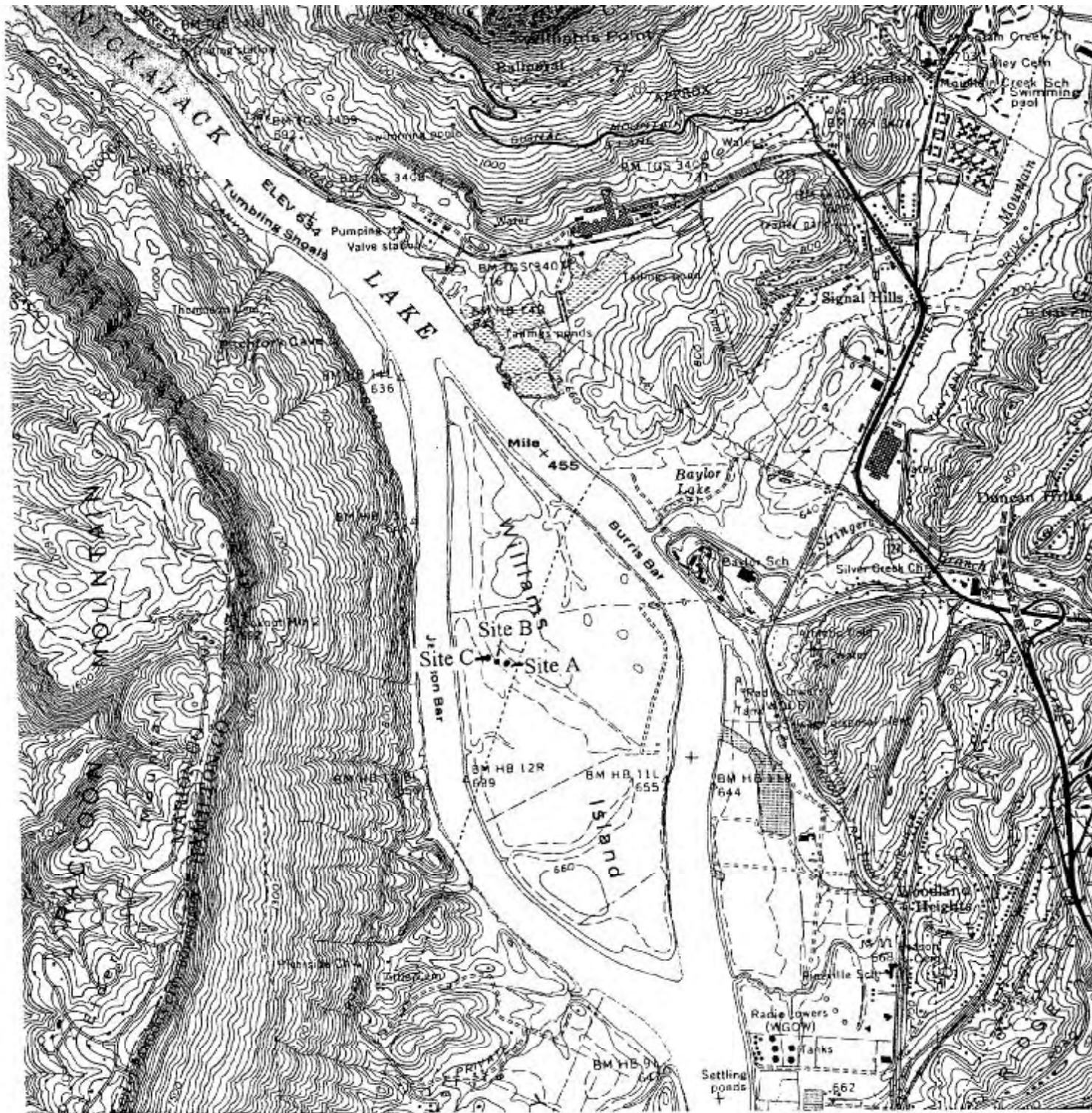
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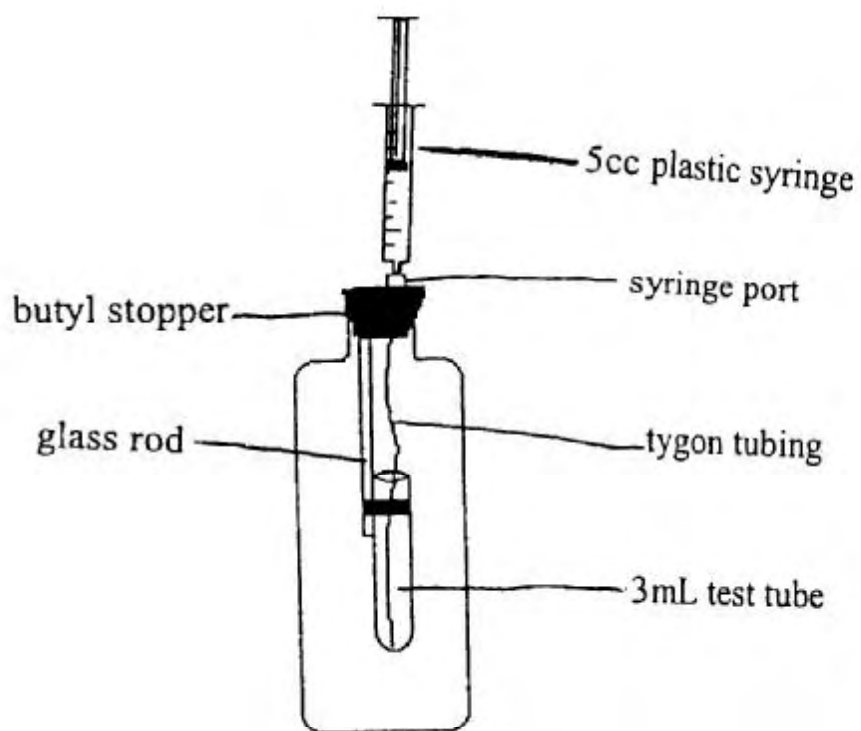
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**Figure 1:** Wetland study area located on William's Island in the Nickajack Reservoir (surface area of island – ~ 350 acres of which ~ 117 acres drains to the wetland; surface area of wetland – ~ 24.5 acres).

**Table 1:** GPS positions of sampling sites and headings for transects, William's Island Wetland 18 Dec. 2002, Microbial Degradation of Simazine.

Site	GPS Coordinates	Heading
A	N 035° 05.270 min. W 085° 20.997 min.	25 m due west of nearest field (near large dead tree; inland side wetland)
B	N 035° 05.283 min. W 085° 21.010 min.	330° from site A (site B middle of wetland)
C	N 035° 05.295 min. W 085° 21.011 min.	340° from site B (site C river side of wetland; shore marker 100° to site C)



**Figure 2:** Illustration of microcosm assembly; William's Island Wetland 18 Dec. 2002, Microbial Degradation of Simazine.

Mean Values, +/- Standard Error, n=3

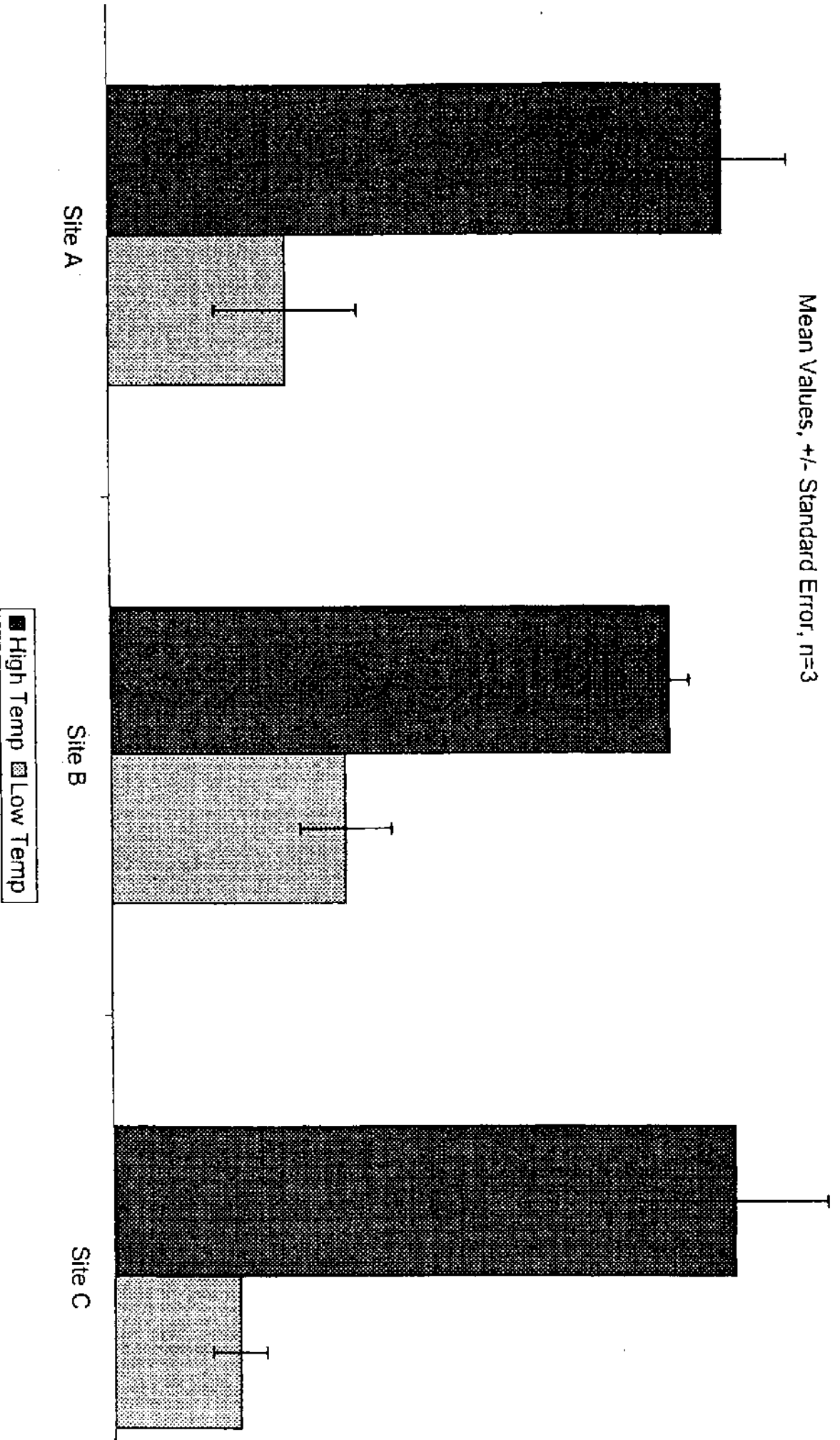


figure 3: Bar graph illustrating the maximum mean rates of simazine mineralization with standard error for both high temperature and low temperature incubations at sites A, B, and C; William's Island Wetland 18 Dec. 2002, Microbial Degradation of Simazine.

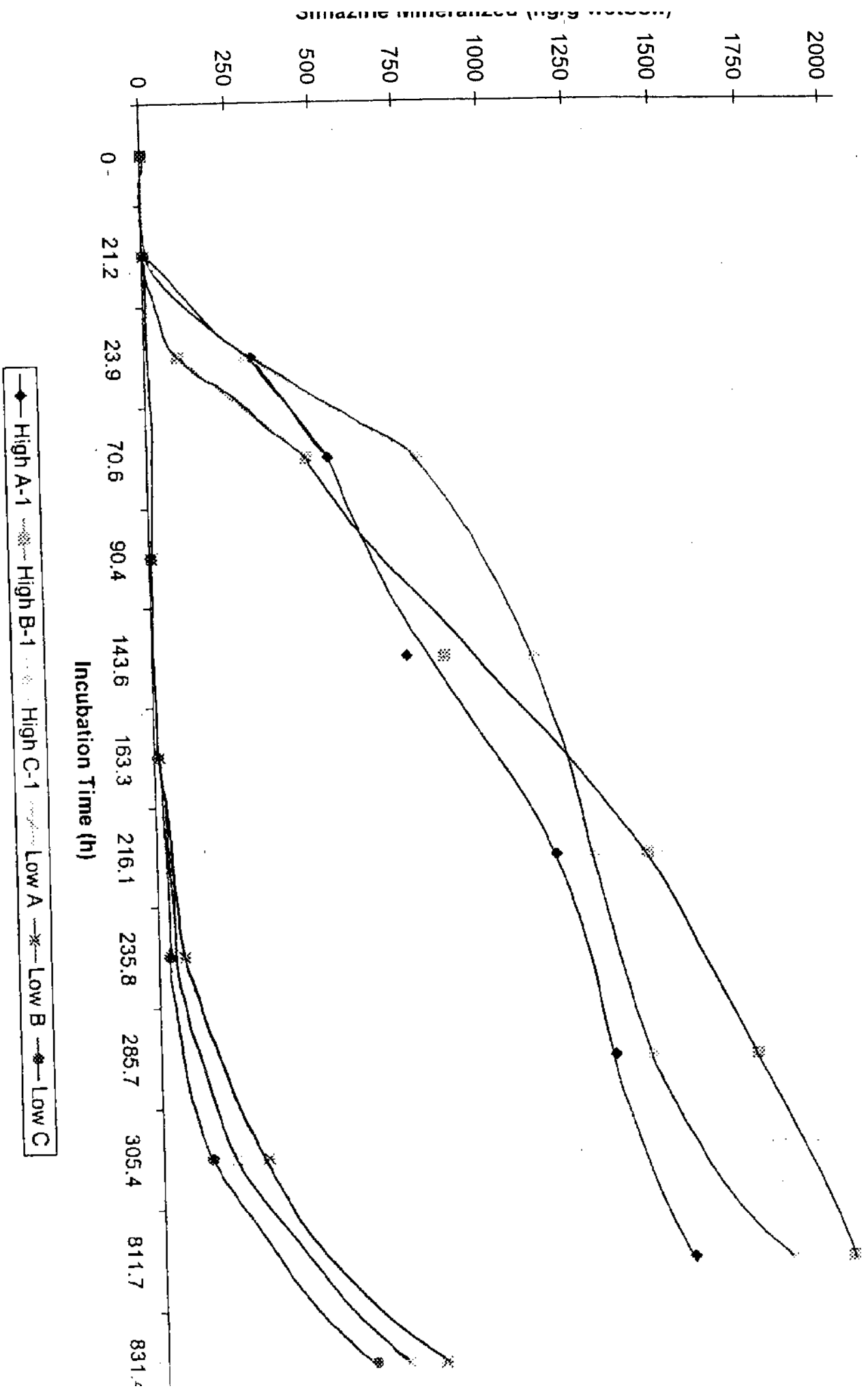
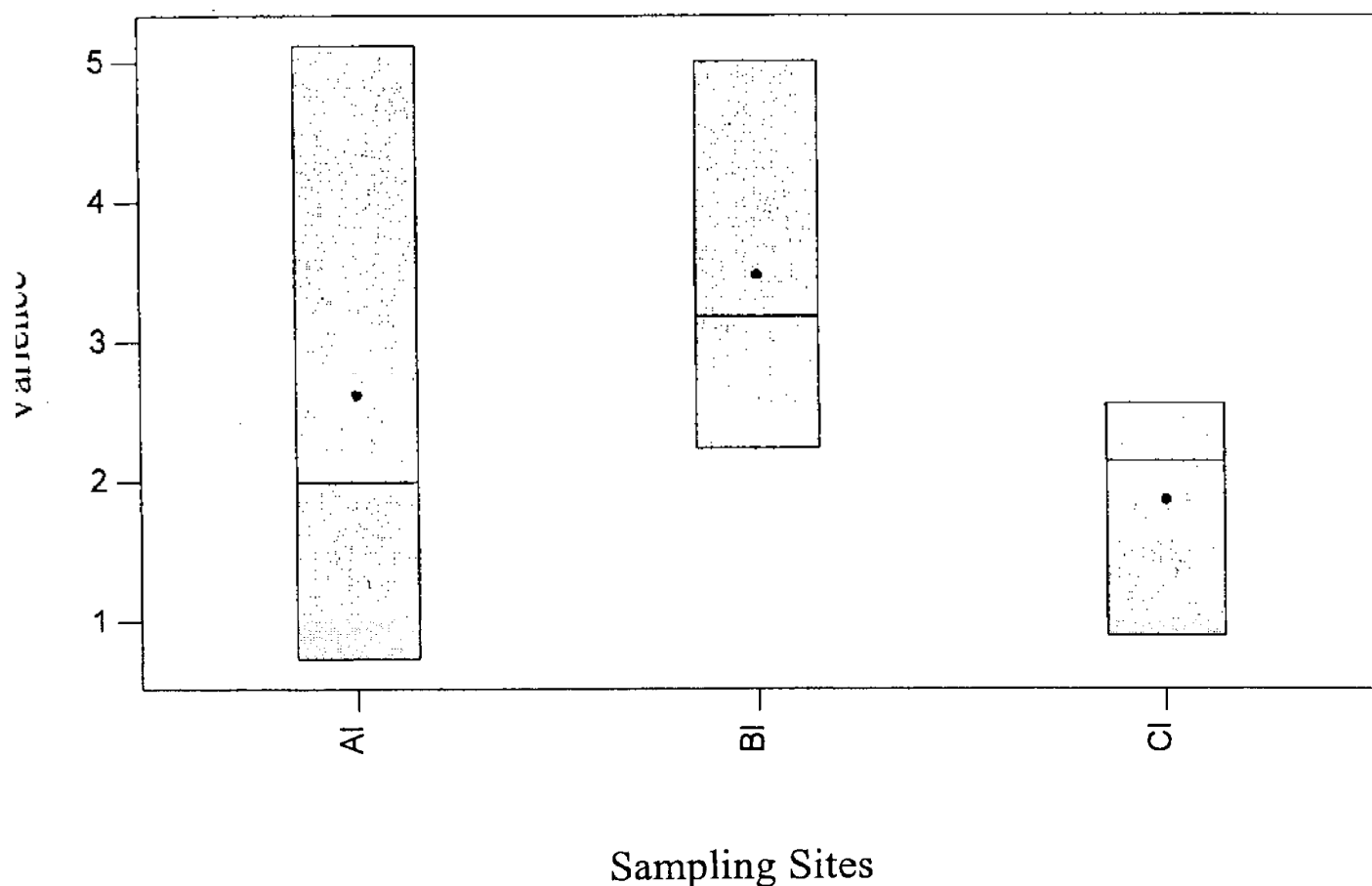


Figure 4: Graph illustrating time course of simazine mineralization for both high temperature and low temperature incubations at si

## Boxplots of Low Temperature Means

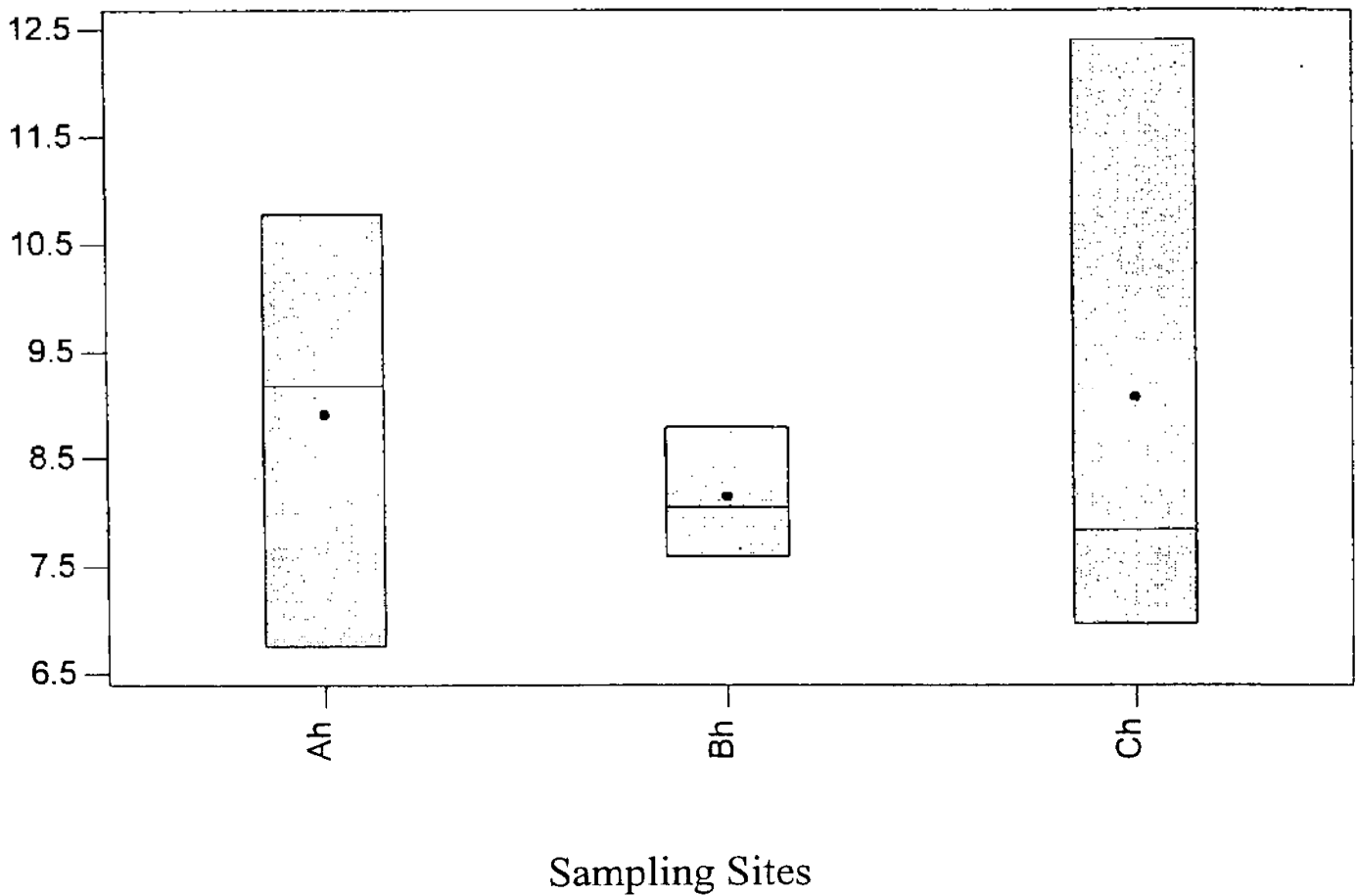
(means are indicated by solid circles)



**Figure 5:** Boxplot of means and standard deviation for low temperature incubation site A, B, and C done in Minitab, William's Island Wetland 18 Dec. 2002, Microbial Degradation of Simazine.

## Boxplots of High Temperature Means

(means are indicated by solid circles)



**Figure 6:** Boxplot of means and standard deviation for high temperature incubation site A, B, and C done in Minitab, William's Island Wetland 18 Dec. 2002, Microbial Degradation of Simazine.

O2 Production from Simazine in Microcosms w/Williams Island Wetland Soils										Raw Data					
Sample Site	Inc Temp	ID#	Soil Wt (g)	Soil % Moisture	Sim Added/D	DPM#1	DPM#2	DPM#3	DPM#4	DPM#5	DPM#6	Tot DPM	M Added Rcv		
A-1-1	25		0.308	74.68	1,542,384	1745.6	2967.8	2290.0	4588.5	1201.4	2034.1	28554.8656	1.92		
A-1-2	25		0.308	74.68	1,542,384	4244.1	1432.9	2038.7	3610.5	1924.9	2096.6	30695.3746	1.99		
A-2-1	25		0.348	52.83	1,542,384	3413.9	1741.6	863.5	1067.2	743.3	2994.5	21647.9089	1.40		
A-2-2	25		0.348	52.83	1,091,105	60.2	4035.0	770.3	423.7	397.4	2560.3	16493.9071	1.51		
A-3-1	25		0.202	57.37	1,091,105	37.9	1499.2	2331.0	706.4	621.0	2682.5	15755.8739	1.44		
A-3-2	25		0.202	57.37	1,091,105	235.1	4442.1	683.4	612.5	418.5	791.6	14366.3041	1.32		
B-1-1	25		0.231	63.69	1,542,384	519.0	2965.3	3081.0	3810.9	1550.2	2167.0	28187.0575	1.83		
B-1-2	25		0.231	63.69	1,542,384	861.1	2496.9	2698.6	4566.7	2943.9	1805.4	30745.3115	1.99		
B-2-1	25		0.291	51.21	1,542,384	1940.1	2073.7	1228.6	475.8	418.3	3335.2	18943.5036	1.23		
B-2-2	25		0.291	51.21	1,091,105	574.9	5520.3	2183.1	730.4	1440.3	4321.6	28541.1658	2.71		
B-3-1	25		0.222	48.76	1,091,105	28.9	2526.4	1788.1	374.8	497.3	2529.0	15489.2494	1.42		
B-3-2	25		0.222	48.76	1,091,105	252.8	4813.1	735.1	467.5	353.5	3013.4	19270.7284	1.77		
C-1-1	25		0.252	39.73	1,542,384	1062.0	1919.6	1971.1	1534.6	2654.0	4911.0	28104.6477	1.82		
C-1-2	25		0.252	39.73	1,542,384	347.7	3085.2	2310.7	2151.2	2500.0	4756.0	30301.3719	1.96		
C-2-1	25		0.242	58.76	1,542,384	2927.3	5292.3	3506.3	1154.4	1923.4	1882.5	33372.4769	2.16		
C-2-2	25		0.242	58.76	1,542,384	1586.7	2451.8	1482.3	1325.6	504.2	4150.3	23001.838	1.49		
C-3-1	25		0.221	51.24	1,091,105	23.8	3395.4	1361.9	299.1	110.1	3004.6	16389.8163	1.50		
C-3-2	25		0.221	51.24	1,091,105	330.6	4147.3	1463.7	401.7	231.6	1500.2	16150.3162	1.48		
A-1-1	8		0.308	74.68	1,091,105	28.3	113.8	68.7	97.7	2023.8	6219.0	17102.3644	1.57		
A-1-2	8		0.308	74.68	1,091,105	25.2	92.3	59.4	96.5	639.7	5028.1	11882.6856	1.09		
A-2-1	8		0.348	52.83	1,091,105	3.0	31.7	18.3	19.2	188.2	4762.5	10045.7593	0.92		
A-2-2	8		0.348	52.83	1,091,105	8.9	43.6	23.6	20.5	922.6	6259.2	14556.9039	1.33		
A-3-1	8		0.202	57.37	1,091,105	0.0	0.0	11.8	332.6	2067.9	3019.5	10863.7108	1.00		
A-3-2	8		0.202	57.37	1,091,105	0.0	23.7	61.5	327.5	2460.4	2746.6	11239.5381	1.03		
B-1-1	8		0.231	63.69	1,091,105	4.1	4.4	4.5	0.0	0.0	1962.6	3951.15227	0.36		
B-1-2	8		0.231	63.69	1,091,105	10.6	48.2	38.1	64.7	2957.5	4927.3	16092.8241	1.47		
B-2-1	8		0.291	51.21	1,091,105	0.0	53.0	194.3	805.0	2123.0	3929.8	14210.107	1.30		
B-2-2	8		0.291	51.21	1,091,105	9.8	135.8	100.2	92.3	602.2	5433.9	12748.4033	1.17		
B-3-1	8		0.222	48.76	1,091,105	6.6	20.5	15.3	163.3	2698.8	4799.5	15407.8839	1.41		
B-3-2	8		0.222	48.76	1,091,105	0.0	11.8	45.5	1692.3	2169.5	3329.3	14496.8488	1.33		
C-1-1	8		0.252	39.73	1,091,105	1.3	17.9	69.4	485.0	1620.2	2790.6	9968.80865	0.91		
C-1-2	8		0.252	39.73	1,091,105	12.0	36.5	12.5	16.8	37.7	5569.6	11370.0844	1.04		
C-2-1	8		0.242	58.76	1,091,105	10.2	65.6	42.9	42.6	945.6	5294.3	12802.4581	1.17		



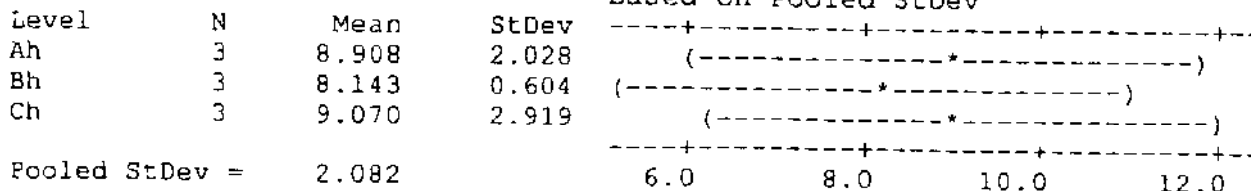
software for both the high and low temperature incubations; William's Island Wetland  
 Dec. 2002, Microbial Degradation of Simazine.

**One-way ANOVA:**

Analysis of Variance for C3

Source	DF	SS	MS	F	P
C2	2	1.47	0.73	0.17	0.848
Error	6	26.00	4.33		
Total	8	27.47			

Individual 95% CIs For Mean  
 Based on Pooled StDev



Tukey's pairwise comparisons

Family error rate = 0.0500  
 Individual error rate = 0.0220

Critical value = 4.34

Intervals for (column level mean) - (row level mean)

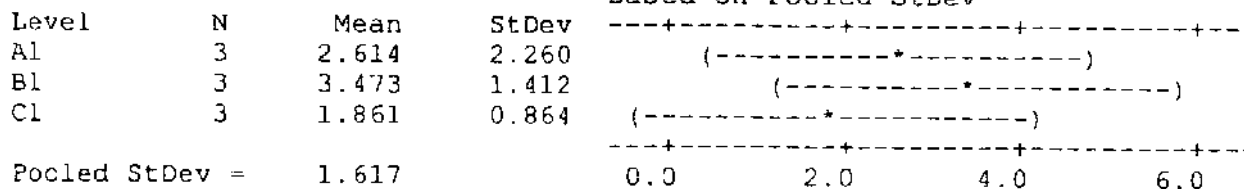
	Ah	Bh
Bh	-4.452 5.980	
Ch	-5.379 5.053	-6.143 4.289

**One-way ANOVA:**

Analysis of Variance for C6

Source	DF	SS	MS	F	P
C5	2	3.90	1.95	0.75	0.514
Error	6	15.69	2.62		
Total	8	19.59			

Individual 95% CIs For Mean  
 Based on Pooled StDev



Tukey's pairwise comparisons

Family error rate = 0.0500  
 Individual error rate = 0.0220

Critical value = 4.34

Intervals for (column level mean) - (row level mean)

	A1	B1
B1	-4.911 3.193	