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# CONTAMINATED SOIL RECOVERY RATE OF A LEACHER COLLECTION SYSTEM

*D.L. Rainey<sup>1</sup>, P.-C. Yuan<sup>1</sup>, J.W. Gentry<sup>2</sup>, and J.J. O'Connell<sup>2</sup>, <sup>1</sup>Department of Technology & Industrial Arts, Jackson State University, PO Box 18480, Jackson, MS, 39217, and <sup>2</sup>Department of Chemical Engineering, University of Maryland at College Park*

**ABSTRACT** Leachate is defined as any liquid, including any suspended components in the liquid, that has seeped, drained, or percolated through a collection system. Within the past few decades leachate collection systems have become valuable tools to scientists in the field of environmental engineering. Vertical column tests have caused collection systems to become even more advanced. They are used by researchers to serve in such capacities as laboratory models for simulating different types of transport in porous media. These two experiments consisted of: 1) various tests to study the column contact time and superficial velocity of water; 2) percolation of the tracer element, benzoic acid, through a sand compacted column. An interchangeable vertical column was constructed of piping material to serve as the testing apparatus. In the first phase, a measure of the column contact time and superficial velocity were attained by pouring one or two liters of water down the column and taking time measurements at different levels. In the second experiment, two hundred milliliters of benzoic acid and one or two liters of water depending on the size of the column were poured down the column. Samples were then taken at designated levels. The test samples were then titrated to measure the amount of base it would take to neutralize the acid.

**KEYWORDS:** leachate, contaminated soil, recovery, reclamation, percolation

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## INTRODUCTION

Leachate is defined as any liquid, including any suspended component in the liquid, that has seeped, drained, or percolated through a collection system. It is commonly generated when water or a liquid comes in contact with a mass and becomes contaminated with waste constituents. Leachate quality depends on the type of collection system used, leaching element, and the type of measurements that are taken. Leachate quality is very difficult to predict because of various factors and may vary considerably.

The quantity of leachate generated is determined by the water or liquid balance of a collection system. Ground water flow or leaching liquid may also contribute to leachate quantity in the saturated zones of a collection system. The liquid output includes evaporation, transpiration, and seepage out

of a system. Leachate output can also be minimized by controlling the various parameters of the water and acid balance.

Leachate collection systems are also used to control leachate levels and somewhat reduces the potential for leachate migration. Low permeability elements such as play sand which is homogeneous is used over soil which is heterogeneous in an effort to prevent cross-contamination of the leached liquid. Consequently, high leachate levels may also increase the potential for unwanted seepage through the system.

Within the past few decades leachate collection systems have become valuable tools to scientists in the field of environmental engineering. Vertical column tests have caused collection systems to become even more advanced. They are used by researchers to serve in such capacities as

laboratory models for simulating different types of transport in porous media. This experiment is divided into two areas: 1) various tests to study the contact time and superficial velocity of water; 2) percolation of the tracer element, benzoic acid, through a sand-compacted column.

## LITERATURE REVIEW

Previous research on leachate quality may provide information for the potential of failure of leachate collection systems by means of various failure mechanisms. Leachate quality may also prove whether or not certain conditions are prone for failure. The absence of an indicator may suggest a small likelihood of failure by the collection mechanism. Analysis of leachate quality is primarily a conceptual technique for critiquing a leachate collection system's performance [1].

Fuel leakage and spill situations require immediate attention for fear of soil and ground water contamination [2]. Reclamation of the contaminated liquid element should include large-scale leachate collection systems that are ready to be installed at a moment's notice. Forced percolation is one of the methods that can be incorporated into a collection system. A soil or liquid vacuum extraction procedure may also be used with the cleanup process [3]. Some of the parameters that should be closely monitored while leaching the area are flow rate and liquid distribution.

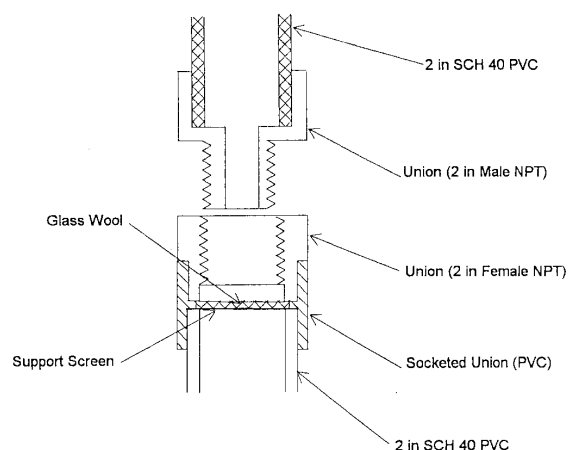
One important factor to be noted when dealing with column leaching is the time-frame involved. Time plays a key role when tracers are introduced into tests to measure the porosity of an element [4]. Time measurements also indicate how long it takes for inorganic solutes to pass through various layers of sand or clay [5]. The amount of

diffusion is of little significance in regard to time in the tests. That is the reason column tests are evaluated more by time and porosity rather than molecular diffusion.

An important goal for conducting waste leaching and soil adsorption tests in the laboratory is to simulate field conditions [6]. Column studies are more similar to field conditions than many other experiments. Batch extraction of leaching data are very similar to the data of other models of column leaching. An example would be corresponding data of the volume of extraction liquid. This is varied to simulate the variability in leaching time [7]. Other experiments dealing with column leaching may include industrial waste leaching, flue gas sludge leaching, and coal fly ash leaching.

Experiments performed on leachate production from municipal solid waste landfills has emphasized the concept of field capacity. Field capacity is defined as the amount of water retained by a porous material after gravity drainage ceases and downward water movement becomes impossible [8]. It also determines the amount of leachate produced. In experiments such as this, the focus is on the amount of fluid draining to the leachate collection system [9]. Also, it is important to average the drainage from various sections of the column.

Flow in vertical columns are very essential to the outcome of an experiment and obtaining desired results. Unsaturated flow is difficult to control and model. As a result, a majority of laboratory column studies involve saturated flow [10]. Flow through a column is also controlled with a constant pump. Pore water velocities concerning flow not only affects chemical elution in porous media, but also affects the nature of



**FIGURE 1. LAYER DIVIDER-CONNECTOR.**

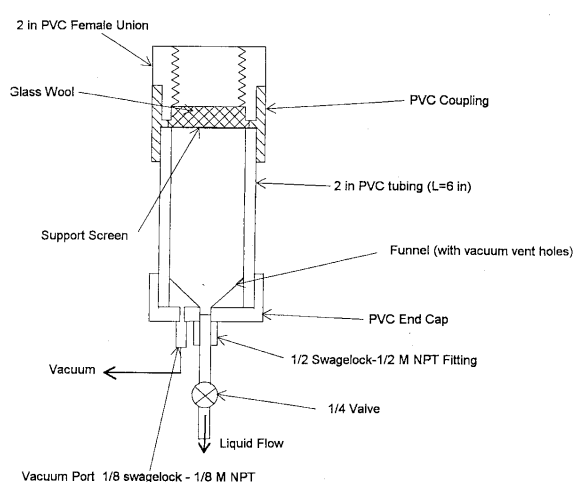
chemical interactions between solid and aqueous phases of the water in a column.

When dealing with acid, certain precautions and rules must be followed. The most important of these rules is to continuously stir the acid mixture. By continuously stirring, one maintains a uniformly acidified condition [11]. Stirring also insures that the pH of the acid is representative of the entire leachate volume of the column.

## METHODS

A vertical column was constructed using two-inch-thick piping material. The column was designed with male and female unions, so the pipes could be used interchangeably. Separating the various size pipes were support screens made out of punched sheet metal and glass wool. These items were used to insure that the sand and the element being leached would not migrate to other parts of the column. Figure 1 shows how the layers are divided and connected to each other.

A funnel was placed at the bottom of the column to help the leached liquid fall smoothly into the collection container. A one-eighth inch hole was cut at the bottom of the column for the vacuum port. The

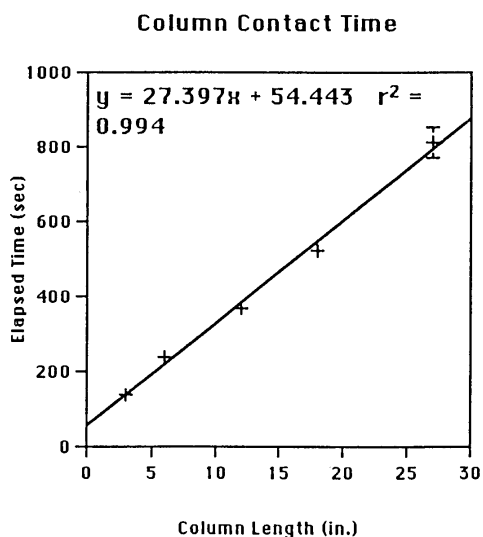


**FIGURE 2. LEACHER COLLECTION SYSTEM.**

vacuum ran up into the column to help draw the liquid down into the bottom of the column. Figure 2 gives a complete layout of the leacher collection system.

The first experiment was broken down into two phases. The first phase was to test the column contact time of water. This is a measure of the elapsed time (seconds) versus column length (inches). The second phase was to test the superficial velocity of water. This is a measure of the volumetric flow rate (ml/sec) versus the column length (inches). The column contact time and superficial velocity of water were attained by connecting various size pipes of compacted sand together and pouring one or two liters of water down the column. It was further broken down into five different column sizes, each consisting of five trials. They were timed to see how long it would take the leached water to come off the column and reach the five hundred milliliters mark in the collection container.

A second experiment was conducted to measure the amount of benzoic acid that was leached through the various size compacted columns. The procedure for this experiment



**FIGURE 3.** COLUMN CONTACT TIME.

was to dilute two hundred milliliters of the acid and then, depending on the size of the column, pouring one or two liters of water down the column. The experiment was broken down into five different column sizes, each consisting of three trials, and ten or twenty measurements of each trial. It is important to note that after each trial was conducted the column was washed with either one or two liters of water to clean out any left-over acid.

After each trial was completed, tests were conducted on each vial of the leached liquid. Five milliliters of benzoic acid were then added to the vial with two drops of phenolphthalein. A base was then added to the solution to measure the amount that it would take to turn the test vial liquid pink. The results from each trial were recorded on a data sheet.

## RESULTS

Despite having a lot of difficulty with the first type of acid test, the outcome of the various tests and experiments conducted on water and acid were overall satisfactory. In

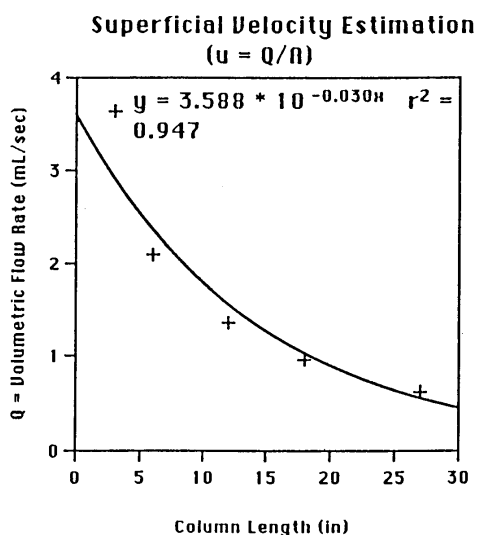
the first experiment an assumption was made on the time-frame of the water to leach through the different sized columns. One theory was that the flow of water would approach zero as the column lengths became larger and larger. Figure 3 proves that assumption to be valid because in reality the flow rate of the leached water moved toward zero as the column length approached infinity.

The second phase of the first experiment dealt with the superficial velocity of water. This was attained by dividing the volumetric flow rate by the column length. An assumption was also made that the volumetric flow rate of water would decrease with increasing column length. Figure 4 proves that theory to be correct. The curve in the figure slants downward because of the decreasing flow rate.

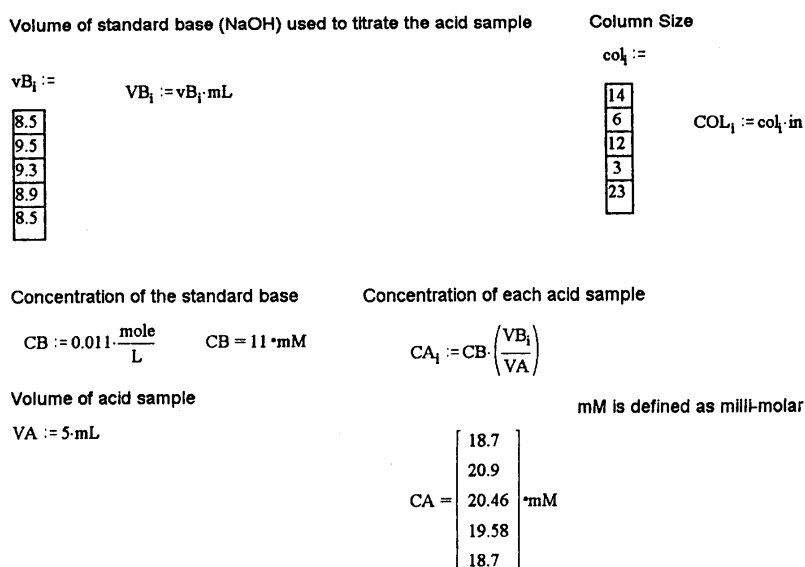
The second experiment dealt with the percolation of the tracer element, benzoic acid, through the various column lengths. A summary of the concentrations of the standard base sodium hydroxide are located in Figure 5. The sodium hydroxide was used to titrate the acid samples in the test vials. Figure 6 is an overlay graph of all the acid tests conducted. It is also an acid concentration and measurement average that contains the peaks and all other points from each of the tests.

Normalizing concentrations of acid is very essential. A curve fitting was used to indicate the experiment's outcome. Consequently, a curve was designed to fit every column size. The dots from the averages were plotted on the curve to see how accurate the tests were.

Figure 7 shows the curve for the three-inch column. Unfortunately, the averages did not correspond very much with the curve. Figure



**FIGURE 4.** SUPERFICIAL VELOCITY ESTIMATION.



**FIGURE 5.** ACID CONCENTRATION DETERMINATION.

8 shows the curve for the six-inch column. As noted, the averages fit directly on top of the curve. This means that the column averages were right on target. Figure 9 indicates the curve-average ratio for the twelve-inch column. The ratios correspond very closely in regard to one another. Figure 10 gives the correlation for the fourteen-inch column. The results show that the curve is

very similar to the averages. The last experiment was the twenty-three-inch column. Figure 11 shows that the curve and average ratios are identical. This means that the test went directly according to plan.

Table 1 contains all of the records for the titrated acid samples. Averages were derived by adding the different measurement levels

Overlay Graph of Combined Tests

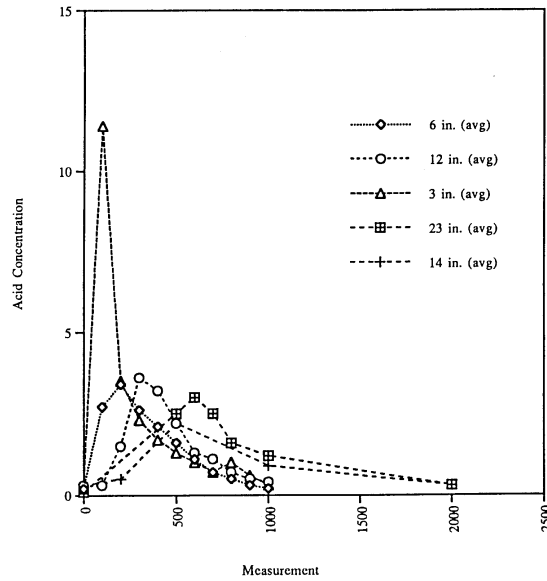


FIGURE 6. OVERLAY GRAPH OF COMBINED TESTS.

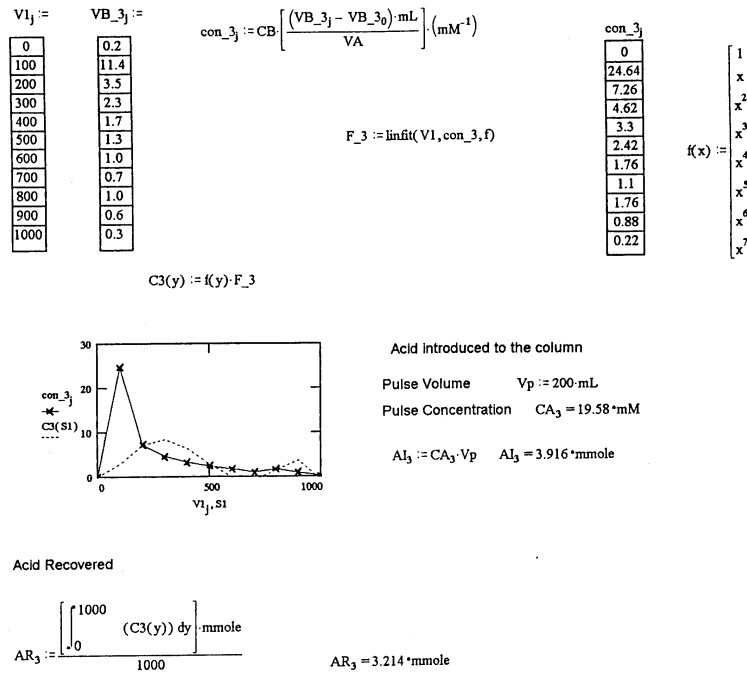


FIGURE 7. THREE-INCH COLUMN.

together for each trial and then dividing by three.

## CONCLUSION

These two experiments proved the two assumptions mentioned earlier in the paper to be correct. In regards to the two-phase

Curve fitting the data

$$COL = \begin{bmatrix} 14 \\ 6 \\ 12 \\ 3 \\ 23 \end{bmatrix} \text{ in} \quad CA = \begin{bmatrix} 18.7 \\ 20.9 \\ 20.46 \\ 19.58 \\ 18.7 \end{bmatrix} \text{ mM}$$

$$V1_j := VB\_6_j := \text{con\_6}_j := CB \cdot \left[ \frac{(VB\_6_j - VB\_6_0) \cdot mL}{VA} \right] \cdot (mM^{-1})$$

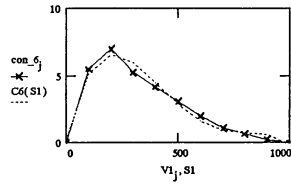
0	0.2
100	2.7
200	3.4
300	2.6
400	2.1
500	1.6
600	1.1
700	0.7
800	0.5
900	0.3
1000	0.2

0	5.5
100	7.04
200	5.28
300	4.18
400	3.08
500	1.98
600	1.1
700	0.66
800	0.22
900	0.22
1000	0

$$f(x) := \begin{bmatrix} 1 \\ x \\ x^2 \\ x^3 \\ x^4 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

S1 := 0, 100.. 1000  
F\_6 := linfit(V1, con\_6, f)

C6(y) := f(y) · F\_6



Acid introduced to the column

Pulse Volume  $V_p := 200 \cdot mL$

Pulse Concentration  $CA_1 = 20.9 \cdot mM$

$AI_1 := CA_1 \cdot V_p \quad AI_1 = 4.18 \cdot mmole$

Acid Recovered

$$AR_1 := \frac{\int_0^{1000} (C6(y)) dy}{1000} \text{ mmole}$$

$AR_1 = 2.975 \cdot mmole$

FIGURE 8. SIX-INCH COLUMN.

$$V1_j := VB\_12_j := \text{con\_12}_j := CB \cdot \left[ \frac{(VB\_12_j - VB\_12_0) \cdot mL}{VA} \right] \cdot (mM^{-1})$$

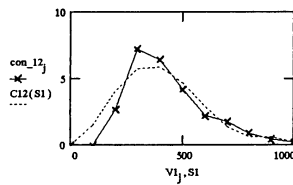
0	0.3
100	0.3
200	1.5
300	3.6
400	3.2
500	2.2
600	1.3
700	1.1
800	0.7
900	0.5
1000	0.4

0	0
100	0
200	2.64
300	7.26
400	6.38
500	4.18
600	2.2
700	1.76
800	0.88
900	0.44
1000	0.22

$$f(x) := \begin{bmatrix} 1 \\ x \\ x^2 \\ x^3 \\ x^4 \\ x^5 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

F\_12 := linfit(V1, con\_12, f)

C12(y) := f(y) · F\_12



Acid Introduced to the column

Pulse Volume  $V_p := 200 \cdot mL$

Pulse Concentration  $CA_2 = 20.46 \cdot mM$

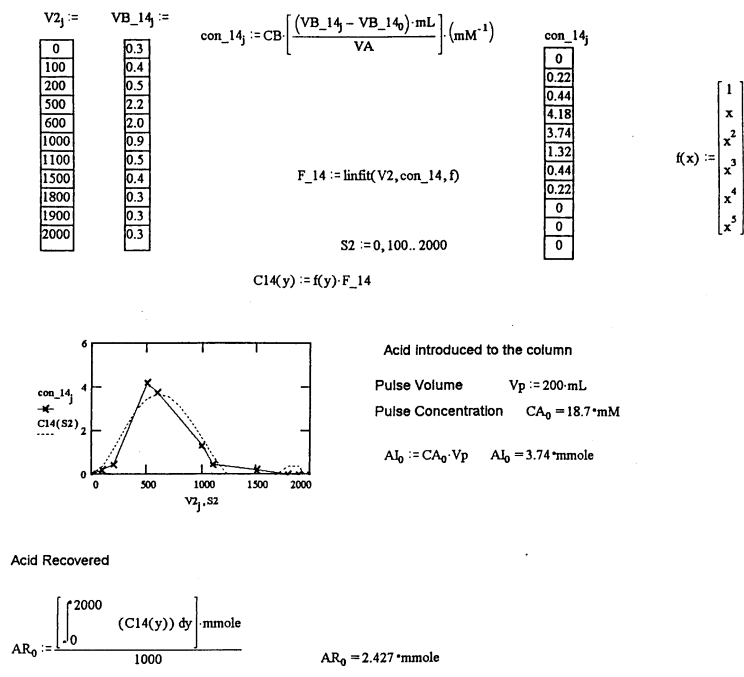
$AI_2 := CA_2 \cdot V_p \quad AI_2 = 4.092 \cdot mmole$

Acid Recovered

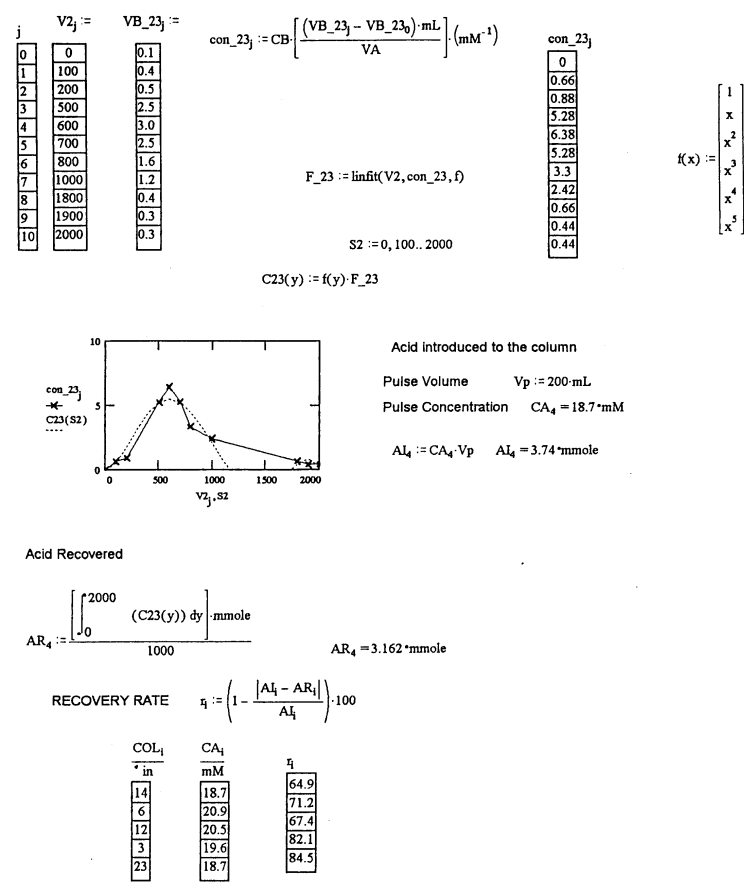
$$AR_2 := \frac{\int_0^{1000} (C12(y)) dy}{1000} \text{ mmole}$$

$AR_2 = 2.757 \cdot mmole$

FIGURE 9. TWELVE-INCH COLUMN.



**FIGURE 10. FOURTEEN-INCH COLUMN.**



**FIGURE 11. TWENTY-THREE-INCH COLUMN.**

experiment with water, both phases show that the flow rate of water approaches zero as the size of the column grows. The second experiment with the benzoic acid was a little more difficult. To obtain a better curve, measurements should be taken every twenty-five milliliters as opposed to every one hundred milliliters. The experiment did show many other interesting facts. The benzoic acid will tend to diffuse in plug flow as opposed to diffusing straight out of the column. Trace elements of crystallized benzoic acid remained in the column after each trial. The averages from each trial are not actual acid concentrations. In reality they are titrated factors.

The experiments conducted in regard to leaching are very important to individuals who work with hazardous materials. Hazardous materials managers are some of the key people who design and construct

leacher collection systems for large corporations and the government. Leaching systems also provide a way for managers to determine how much toxic material or liquid has leached through an element into the liner of a hazardous waste landfill. As we move into the twenty-first century, hazardous materials managers will be at the forefront of technology in all aspects of collecting hazardous, toxic, or nuclear materials that have contaminated and polluted our environment.

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**TABLE 1.** TITRATED ACID SAMPLES.

	1	2	3	4	5	6	7
	Measurement	Column 2	14 in. (avg.)	6 in. (avg.)	12 in. (avg.)	3 in. (avg.)	23 in. (avg.)
1	0		0.3	0.2	0.3	0.2	0.1
2	100		0.4	2.7	0.3	11.4	
3	200		0.5	3.4	1.5	3.5	
4	300			2.6	3.6	2.3	
5	400			2.1	3.2	1.7	
6	500		2.2	1.6	2.2	1.3	2.5
7	600			1.1	1.3	1	3
8	700			0.7	1.1	0.7	2.5
9	800			0.5	0.7	1	1.6
10	900			0.3	0.5	0.6	
11	1,000		0.9	0.2	0.4	0.3	1.2
12	1,100						
13	1,200						
14	1,300						
15	1,400						
16	1,500						
17	1,600						
18	1,700						
19	1,800						
20	1,900						
21	2,000		0.3				0.3

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