Leaching of Arsenic from Iron Oxide Impregnated Brick Sands (Shapla Filter Media) Using Common Chemicals and Water

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Abstract

Leaching of Arsenic from high Arsenic loaded iron oxide impregnated brick sands (IOI CBCM) was investigated using common household chemicals like common salt and soda ash, the industrial chemicals caustic soda and the phosphates used as fertilizers such as potassium hydrogen phosphate and TSP. Leaching by ordinary ground water was also investigated on the arsenic saturated iron oxide impregnated brick sands from filters. A 10% caustic soda solution could leach ~95% arsenic, 20% sodium chloride solution could leach ~17.28%, 10% sodium carbonate solution 11.34%, 10% potassium dihydrogen phosphate solution 11.85%, and a 10% TSP solution could leach 34.56% arsenic from high arsenic rich (~1000 ppm As) iron oxide impregnated brick sands. Since ordinary water in the environment rarely contain such high concentration of chemicals, very little dissolution of As from arsenic loaded brick sands is expected. Natural groundwater showed negligible or no leaching from waste arsenic-rich iron oxide impregnated brick sands from filters both in flow and static tests at pH 4 and 7.

INTRODUCTION

In a previous work (Islam and Hossain, 2001) we used chemically treated brick sands to remove or to adsorb arsenic from groundwater or prepared solution. Arsenic adsorption capacities of the various brick sands were determined. When chemically treated brick sands were used to remove arsenic from water, after a certain period of use the brick sands become loaded with As and the adsorption capacities of the brick sands were decreased with time. In this study, experiments were performed to find out the effects of commonly used chemicals on arsenic-rich brick sands. Leaching experiments were done on the As loaded brick sands to assess any possible leaching of As in the environment and the possibility of recovery of As from the sands. The commonly used chemicals used in this study are Na_2CO_3 used as washing soda, NaCl used as common salt, TSP and KH_2PO_4 used as fertilizer. These chemicals may be present in village ponds and water bodies and it is important to know their possible effects on As loaded brick sands, for possible environmental impacts. Groundwater may also leach As from loaded brick sands and the effect of groundwater is also investigated in this study. The following sections provide a summary of the experimental procedure followed in this study and the corresponding experimental results.

LEACHING OF ARSENIC FROM BRICK SANDS WITH SODIUM HYDROXIDE SOLUTION

NaOH is a strong base used in leaching of many minerals, such as sulfides and oxides. In the leaching of As loaded brick sands, it is expected that any strong bond formation will be easily broken by caustic soda. With this expectation the loaded brick sands were leached for different time periods.

Experimental Procedure

At first 20 gm of (-3.15+2) mm mesh FeSO4 treated roasted brick sands, which was loaded with 168.8 x 10^{-4} gm As was taken in a beaker. Then 100 ml of 10% NaOH solution was added to the beaker. The brick sands and caustic mixture was slowly agitated by a stirrer. After the first 20-minute of stirring, 2.0 ml. of fluid (10% NaOH solution) was withdrawn and tested for arsenic by the SDDC – method. After the second 20-minute stirring, 1.0ml of fluid was withdrawn from the beaker and tested for arsenic. This process was repeated for the 3rd 20-min., 4th 20-min., 5th 20-min. and 6th 20-min. cycles. After a total of 120 minutes of leaching,

arsenic concentration in the remaining fluid in the beaker was determined. After each cycle, the % As leached was calculated.

Results and Discussion

The experimental results are shown graphically in Fig.1. It is shown that after the first 20 minutes of stirring with 10% NaOH solution, aqueous arsenic concentration was 85.0 ppm, which corresponds to a leaching of about 50.4% of the total As in brick sands. After the 2nd 20-minute stirring, aqueous arsenic concentration was 105.0 ppm, and the corresponding leaching was about 62.6%. After the 6th 20-minute cycle (i.e., after 120 minutes stirring) total leached or recovered As was 94.8%. Practically all As is leached in eighty minutes with 10% NaOH. Thus it is observed that strong caustic soda solution is an effective reagent for the recovery of As. However whether the leached brick sands can be used for adsorption of As again was not studied in this study.

The experiment showed that the adsorbed As is unstable in the presence of caustic water. This indirectly shows very high pH (14.0) will not favor arsenic adsorption and favor desorption. However such conditions are rarely encountered in natural water.

LEACHING OF ARSENIC FROM BRICK SANDS WITH SODIUM CHLORIDE SOLUTION

In the previous experiment it was shown that NaOH solution has high ability to leach As from As loaded brick sands. In this study we investigated the ability of NaCl solution to leach As from brick sands.

Experimental Works

At first 20 gm of (-3.15+2) mm mesh $FeSO_4$ treated roasted brick sands loaded with 185.2 x 10-4 gm As was taken in a beaker. Then 100 ml of 20% NaCl solution was added to the beaker. The 20% solution and brick sand mixture was slowly agitated by a stirrer. After the first 1-hour stirring, 5-ml of the fluid (20% NaCl solution) was withdrawn and tested for arsenic concentration by the SDDC colorimetric method. After the 2nd 1-hour stirring, another 5.0ml of solution was withdrawn and tested for arsenic concentration as before. This process was repeated for the 3rd 1-hour, 4th 1-hour, 5th 1-hour, and 6th 1-hour and 7th 1-hour cycles. After a total 7 hours leaching, arsenic concentration in the remaining NaCl solution was determined. After each cycle, the % As leached was calculated.

Results and Discussion

The experimental results are shown graphically in Fig 2. It shows that after the first 1-hour stirring with 20% NaCl solution, aqueous arsenic concentration was 12.4 ppm, which corresponds to a leaching of about 6.7% of the total As present in brick sands. After the 2nd 1-hour stirring with 20% NaCl solution, aqueous arsenic concentration was 21.0 ppm, and corresponding leaching was about 11.3%. After 7th 1-hour cycle, total recovered As was about 17.3%

The experiment shows that a strong solution of NaCl has poor ability to leach As from loaded brick sands. The leaching virtually stops after 5 hours of leaching with 17.28% leaching of As. Thus ordinarily present salt in the environment will have little effect on the arsenic adsorbed by $FeSO_4$ treated roasted brick sands. These results also suggest that NaCl solution cannot be used to remove arsenic from brick sands.

LEACHING OF ARSENIC FROM BRICK SANDS WITH SODIUM CARBONATE SOLUTION

Na_2CO_3 is a strong base like NaOH, so it is expected that Na_2CO_3 might have leaching properties similar to NaOH. The washing soda is widely used in rural households. The Na_2CO_3-rich water may cause leaching of arsenic from As loaded brick sands.

Experimental Works

At first 20 gm of (-3.15+2) mm mesh $FeSO_4$ treated roasted brick sands loaded with 185.2 x 10-4 gm As was taken in a beaker. Then 100 ml of 10% Na_2CO_3 (pH = 13.02) solution was added to the beaker. The beaker was then slowly agitated by a stirrer. After the first 1-hour stirring, 5.0 ml of fluid (10% Na_2CO_3 solution) was withdrawn from the beaker and tested for arsenic concentration using the SDDC method. Again after the 2nd 1-hour stirring, another 5.0 ml of solution was withdrawn and tested for arsenic as before. This process was repeated for the 3rd 1-hour, 4th 1-hour, 5th 1- hour, 6th 1-hour an 7th 1-hour cycles. After a total of 7 hours of leaching, the As in the remaining 10% Na_2CO_3 solution was determined. After each cycle, the % As leached was calculated.

Results and Discussion

The experimental results are shown graphically in Fig 3. It shows that after the first 1-hour stirring with 10% Na_2CO_3 solution, aqueous arsenic concentration was 14.0 ppm, which corresponds to a leaching of about

7.6% of the total As present in brick sands. After the 2nd 1-hour stirring, aqueous arsenic concentration was 21.0 ppm, corresponding to a leaching of about 11.3%. After 7th 1-hour cycle, total recovered As was only about 18.4%.

The experimental results show that a strong solution of Na_2CO_3 cannot cause significant leaching of adsorbed arsenic from brick sands. Only 18.4% of the As present in brick sand is leached by strong Na_2CO_3 solution. Thus, the Na_2CO_3 solution would be ineffective for regeneration of spent brick-sand filter media.

LEACHING OF ARSENIC FROM BRICK SANDS WITH KH_2PO_4 SOLUTION

Soil contains phosphates either as insoluble phosphates or soluble phosphates. This experiment was conducted to examine the possibility of As leaching by phosphates. A KH_2PO_4 solution was used as a leaching solution.

Experimental Works

At first 10gm of (-3.15+2) mm mesh $FeSO_4$ treated roasted brick sands loaded with 84.4 x 10-4 gm As was taken in a beaker. Then 10 0ml of 10% KH_2PO_4 solution were added to the beaker. The beaker was then slowly agitated by a stirrer. After the first 20-minute stirring, 2.0 ml of fluid (10% KH_2PO_4 solution) was withdrawn from the beaker and tested for arsenic using the SDDC method. Again after the 2nd 20-minute stirring, another 2.0 ml fluid was withdrawn from the beaker and was tested for arsenic. This process was repeated for up to 6th 20-minute cycle. After a total of 120 minutes leaching, the arsenic concentration in the remaining KH_2PO_4 solutions was determined. The pH of the solution was 4.3-4.42. After each cycle, the % As leached was calculated.

Results and Discussion

The experimental results are shown graphically in Fig 4. It shows that after the first 20 minutes of stirring with 10% KH_2PO_4 solution, aqueous arsenic concentration was 2.5 ppm, which corresponds to a leaching of about 3.0% of the total As present in brick sands. After the 2nd 20-minute stirring, aqueous concentration was 6.25 ppm, corresponding to a leaching of about 7.4% of the As present. After the 6th 20-minute cycle, total recovered As was 11.9%.

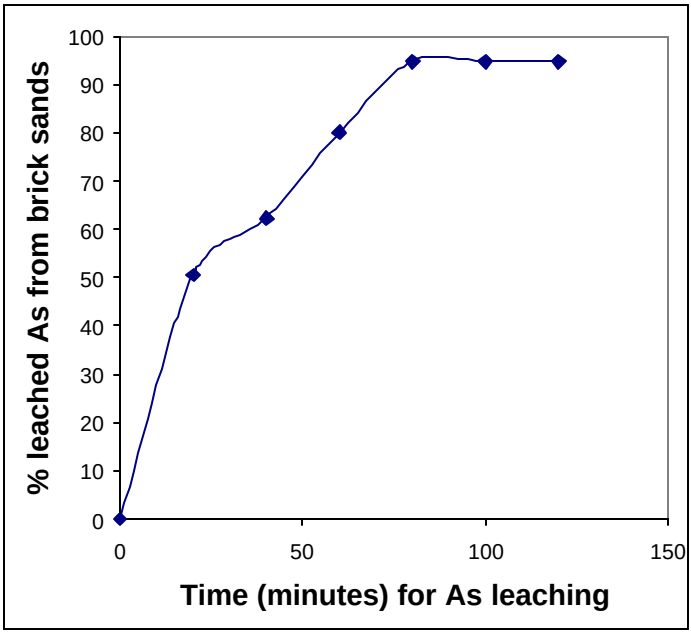

Figure 1: Variation of As leaching with time using NaOH solution

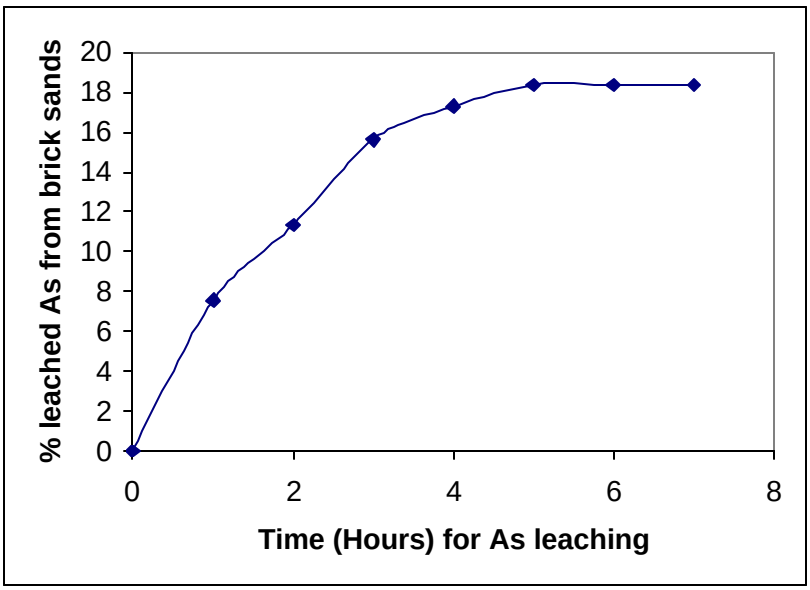

Figure 2 : Variation of As leaching with time using NaCl solution

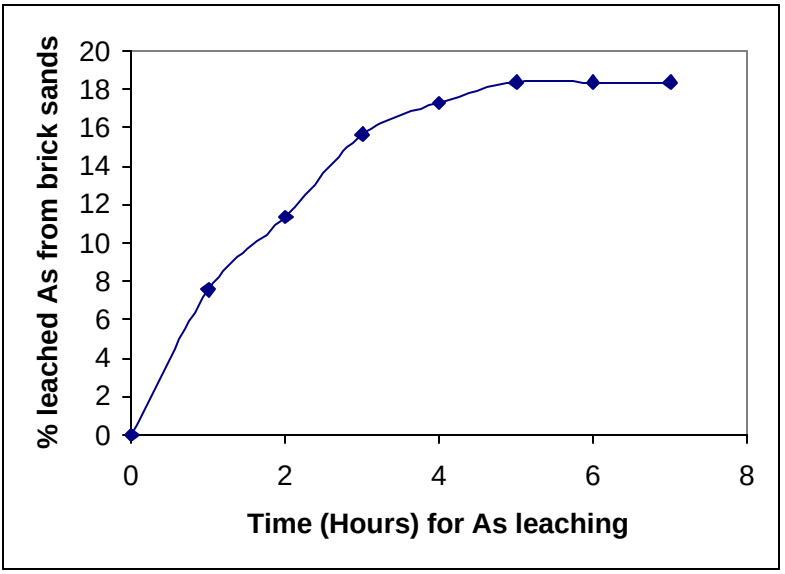

Figure 3: Variation of As leaching with time using Na_2CO_3 solution

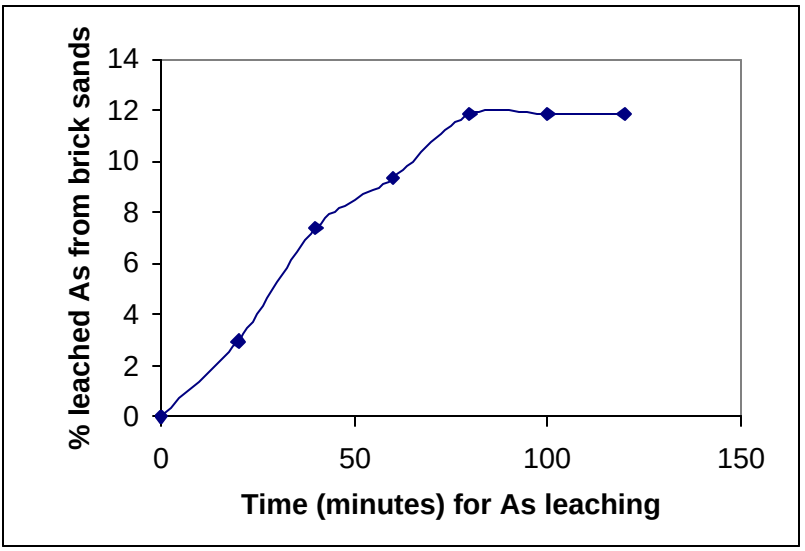

Figure 4: Variation of As leaching with time using KH_2PO_4 solution

It is seen that only about 11.9% As can be leached from brick sands by the phosphate bearing leaching solution and maximum leaching is achieved within 80 minutes. No more leaching occurs after 80 minutes. Thus even a 10% solution of KH_2PO_4 can not fully desorb arsenate/ arsenite adsorbed in brick sands. Thus it appears that As can not be leached significantly by PO_4 present in water of ponds or in soil. This has also been shown indirectly in an earlier work (Islam and Rahman, 2001).

LEACHING OF ARSENIC FROM BRICK SANDS WITH TRIPLE SUPER PHOSPHATES SOLUTION

Super phosphates are widely used for agricultural purpose. The soluble phosphates, derived from phosphate fertilizers, may desorb the adsorbed arsenic from brick sands. A study was therefore instituted to see the effect of super phosphates on the As release from As loaded brick sands.

Experimental Works

At first 9 gm of (-3.15+2) mm mesh $FeSO_4$ treated roasted brick sands loaded with 75.9 x 10-4 gm As was taken in a beaker. Then 100 ml of 10% TSP(pH = 2.97) solution was added to the beaker. The beaker was then agitated slowly by a electric stirrer. After the first 20 minutes of stirring, 2.0ml fluid (10% TSP solution) was withdrawn from the beaker and tested for arsenic using the SDDC method. Again after the 2^{nd} 20-minute stirring, another 2.0 ml solution was withdrawn from the beaker and tested for arsenic. This process was repeated upto 6 20-minute cycles. After a total of 120 minutes of leaching, arsenic concentration in the remaining 10% TSP solution was determined. After each cycle, the % As leached was calculated.

Results and Discussion

The experimental results are shown graphically in Fig 5. It shows that after the first 20 minutes of stirring with 10% TSP solution, aqueous concentration was 2.5 ppm, which corresponds to a leaching of about 3.3% of the total As present in brick sands. After the 2^{nd} 20-minute stirring, aqueous arsenic concentration was 3.0 ppm and the corresponding leaching was about 6.6%. After the 6^{th} 20-minute cycle, total recovered As was about 34.6%.

It is seen that only about 34.6% of adsorbed arsenic can be leached by the TSP solution and the maximum leaching is achieved within 100 minutes. No more leaching occurs after 100 minutes. Thus TSP shows higher leaching of arsenic from loaded brick sands than KH_2PO_4. This can

be explained on the basis of pH of the leach solution, which is quite low (2.97) compared to KH_2PO_4 solution (4.3 – 4.4). At lower pH values, more desorption of adsorbed arsenic is expected. The data shows that only about 1/3 of the total arsenic present was each out. However it is unlikely that such highly acidic conditions will be encountered in practice in the agricultural lands, ponds or ditches, where arsenic-rich treatment wastes may be disposed of by the users.

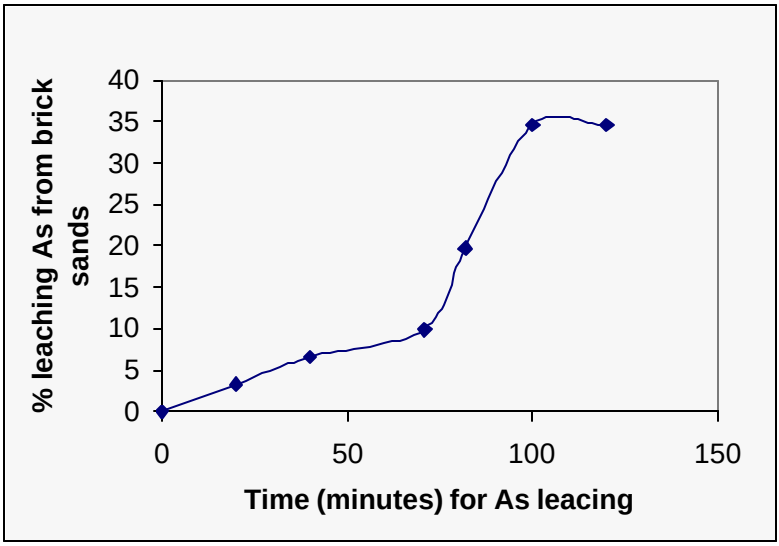

Figure 5: Variation of As leaching with time using TSP solution

LEACHING OF ARSENIC FROM BRICK SANDS WITH WATER UNDER DIFFERENT CONDITIONS

Brick sands roasted with $FeSO_4$ (IOI CBCM) under the same conditions as in other cases were used for the construction of filters ("Shapla" filter) for removing arsenic from tubewell water. After saturation of the Shapla filter media, it was tested for the release of As from the spent media using ordinary water at different pH values. This experiment was done for the possible effect of the Arsenic-rich brick sands on the environment.

Experimental Works

Two filters were constructed with 20-liter plastic buckets with a hole at the bottom for controlled release of water designed for the filter ("Shapla" filter) operation. The buckets were filled with 10 kg of the $FeSO_4$ treated

roasted brick sands. 15 liters of tube well water with arsenic content of about 0.5 ppm was passed through the filters daily for several months until arsenic level in the filtered water reached 0.05 ppm. The arsenic content of the saturated media was 92 ppm as determined by analysis.

The saturated media was then tested for leaching of arsenic by arsenic free municipal tap water adjusted at two pH values (7 and 4). Two methods of arsenic leaching were conducted using:

(i) a continuous flow of water through the saturated media and
(ii) a static method where a quantity of the saturated media was contacted with a definite volume of water for a definite time.

In the first method tap water at pH 7 was poured into the filters and 20 liters of tap water was passed through the filters according to the schedule in Table 1 using the same flow rate for arsenic removal. The effluent water was analyzed for As content by the Merck test kit. The experiment was done for 20 days. The pH of the media was also noted.

In the second method a 20 gm portion of the saturated media was contacted with 100 ml of water at pH 4 (using HCl as pH adjustment). The mixture was kept for 3 hours with occasional stirring. After contact the As level in the filtered water was tested by Merck test kit. The experiment was repeated twice a day for 20 days with the same spent media. The pH of the filtered water was noted.

Results and Discussion

The data in the Table 1 show that almost no or negligible amount of As was detected in the effluent water from the filters containing arsenic saturated brick sands. The results indicate that almost no or negligible amount of As will be released to the environment if the As saturated $FeSO_4$ treated brick sands comes in to contact with flowing water in the environment. The data also shows that As leaching from waste $FeSO_4$ treated brick sands is negligible even at pH 4 in the static test.

This shows that As release will also be negligible in the environment if the As saturated brick sands comes in contact with stagnant water, such as ponds or large water bodies. The fact that the As in the $FeSO_4$ treated brick sands is very strongly bonded is also supported by an independent laboratory in the United States of America. However if the $FeSO_4$ treated roasted brick sands is loaded to a very high level near 1000 ppm using synthetic water with very high As concentration (400-800 ppm) , leaching tests show some release of As from brick sands. However this extreme high loading is not obtained with ordinary arsenic containing natural water. This is due to the variable loading capacity of brick sands with

concentration of As in water and time as given in a previous report (Islam and Rahman, 2001).

Table 1 : Wash test of used media for arsenic leaching

Date & Day	Contact Time	Collection Time	Bucket-01 Flow Test			Bucket-02 Flow Test			Static Leaching		
			Qty (L)	PH	As (ml/L)	Qty (L)	PH	As (ml/L)	Quantity (L)	pH	As(mg/L)
Day-01	8-12 AM	12:00 AM	12:00 AM	8	Slight color	10	8.1	Slioght color	100 ml	4	Slight color
	4-8PM	8:00 PM	10	8	Do	10	8	Do	100 ml	4	Do
Day-02	8-12 AM	12:00 AM	10	8.1	Do	10	8	Do	100 ml	4	Do
	4-8PM	8:00 PM	10	8.1	Do	10	8	Do	100 ml	4	Do
Day-03	8-12 AM	12:00 AM	10	8.1	Do	10	8	Do	100 ml	4	Do
	4-8PM	8:00 PM	10	8.2	Do	10	7.9	Colorless	100 ml	4	Colorless
Day-04	8-12 AM	12:00 AM	10	8.2	Colorless	10	7.9	Nill	100 ml	4	Do
	4-8PM	8:00 PM	10	8.1	Nill	10	8	Nill	100 ml	4	Do
Day-05	8-12 AM	12:00 AM	10	8.1	Nill	10	8	Nill	100 ml	4	Do
	4-8PM	8:00 PM	10	8.1	Nill	10	8.1	Nill	100 ml	4	Do
Day-06	8-12 AM	12:00 AM	10	8	Nill	10	8.1	Nill	100 ml	4	Do
	4-8PM	8:00 PM	10	8	Nill	10	8.1	Nill	100 ml	4	Do
Day-07	8-12 AM	12:00 AM	10	8	Nill	10	8.1	Nill	100 ml	4	Do
	4-8PM	8:00 PM	10	8.1	Nill	10	8.2	Nill	100 ml	4	Do
Day-08	8-12 AM	12:00 AM	10	8.1	Nill	10	8.2	Nill	100 ml	4	Do
	4-8PM	8:00 PM	10	8.1	Nill	10	8.2	Nill	100 ml	4	Do
Day-09	8-12 AM	12:00 AM	10	8.2	Nill	10	8.3	Nill	100 ml	4	Do
	4-8PM	8:00 PM	10	8.2	Nill	10	8.3	Nill	100 ml	4	Do
Day-10	8-12 AM	12:00 AM	10	8.2	Nill	10	8.3	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.2	Nill	10	8.3	Nill	100 ml	4	Do
Day-11	8-12 AM	12:00 AM	10	8.2	Nill	10	8.3	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.2	Nill	10	8.3	Nill	100 ml	4	Do
Day-12	8-12 AM	12:00 AM	10	8.2	Nill	10	8.3	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.2	Nill	10	8.2	Nill	100 ml	4	Do
Day-13	8-12 AM	12:00 AM	10	8.2	Nill	10	8.2	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.2	Nill	10	8.2	Nill	100 ml	4	Do
Day-14	8-12 AM	12:00 AM	10	8.2	Nill	10	8.2	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.3	Nill	10	8.3	Nill	100 ml	4	Do
Day-15	8-12 AM	12:00 AM	10	8.3	Nill	10	8.3	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.3	Nill	10	8.3	Nill	100 ml	4	Do
Day-16	8-12 AM	12:00 AM	10	8.3	Nill	10	8.4	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.4	Nill	10	8.4	Nill	100 ml	4	Do
Day-17	8-12 AM	12:00 AM	10	8.4	Nill	10	8.4	Nill	100 ml	4	Do
	4-8 PM	8:00 PM	10	8.4	Nill	10	8.3	Nill	100 ml	4	Do
Day-18	8-12 AM	12:00 AM	10	8.4	Nill	10	8.3	Nill	100 ml	4	Do
	4-8 PM	8.00 PM	10	8.4	Nill	10	8.3	Nill	100 ml	4	Do
Day-19	8-12 AM	12.00AM	10	8.4	Nill	10	8.4	Nill	100 ml	4	Do
	4-8 PM	8.00PM	10	8.4	Nill	10	8.4		100 ml	4	Do

Remarks: Bucket 01 & 02 flow test leaching with tap water; Static test with 20 gm used media from bucket 02 with 100 ml pH=4.0 water.

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