

# REMOVAL OF CR FROM THE CONTAMINATED SOIL BY THE SOIL WASHING TECHNIQUE USING A MODIFIED BENCH SCALE MODEL

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**ABSTRACT:** In present scenario, various hazardous waste sites exist in India as well as in other countries like USA because of the waste released from the various industries, accidental surface spills and leaking underground tanks etc. It is dangerous for both the human health and the environment. Various heavy metals accumulate in the soil at these sites due to the waste materials which ultimately contaminate both the ground water and drinking water. Several technologies were employed from the several years to remove the heavy metals from the contaminated soil. Soil washing is one of the ex-situ techniques which is cost effective and easy in operation and used in the present study. A modified bench scale model/rotating soil washing unit was fabricated to remove the Cr from the contaminated soil. H<sub>2</sub>SO<sub>4</sub> solution of different normality was used as the washing solution and reaction was carried out for the different tumbling time ranging from 1-24 h. Results supported the effectiveness of this rotating soil washing unit in Cr removal from the artificially contaminated soil. Chromium removal efficiency was found to be minimum 34.18 % and maximum 69.58% on the use of the 0.5N to 4N concentrated sulphuric acid for different interval of time. This rotating soil washing machine/bench scale model can also be employed in case of mixed contaminants such as pesticides and volatile organic compounds. The results confirmed that the new soil washing process can remove the heavy metals from the contaminated soil efficiently and economically.

**Keywords:** Soil washing, bench scale model, ex-situ technique

## Introduction

There are various hazardous waste sites in the United States (US) due to the severe contamination by the improper waste disposal, accidental surface spills, industrial and military activities, leaking underground tanks and spillage of chemicals such as pesticides, wood preserving agents, and petroleum products (USEPA, 2000,1). Several methods of cleanup of these sites were employed to protect the human health from its dangerous effects. Site cleanup such as industrial waste sites is also essential which involves the excavation of soil and waste from the site and later on their off-site disposal (2, 3).

Heavy metals like chromium Cr, cadmium Cd, Arsenic (As), Zinc (Zn) and lead Pb etc. are the major pollutants present in the soil at the industrial sites (4, 5). Metal rich soils are potential threat for the human health as well as for the environment as it contaminates the ground water

and surface water. Chromium is one among the major heavy metal pollutant present in the contaminated soil and exists in natural soil in two forms hexavalent and trivalent forms ranging in the concentration of 5-120mg/kg (6).

Trivalent chromium is mainly the natural form and is essential for the human nutrition thus nontoxic in nature whereas hexavalent form usually accumulates in the food chain thus affects the normal human physiology and causes the several diseases like skin irritation and lung carcinoma. Trivalent chromium is less toxic than the hexavalent form as it does not migrate from one place to another with the ground water and precipitated as oxides, hydroxides and oxyhydroxides. However hexavalent form is more soluble in water over the entire pH range thus spread contamination along with the ground water thus more toxic in nature (7). The U.S. Environmental Protection Agency (EPA) classified

Chromium VI as a Group A Carcinogenic element for humans. Hexavalent as well as trivalent form both can cause several diseases such as allergic contact dermatitis (8). Hence reduction of hexavalent form of Cr to trivalent form is essential to remove the soil contamination which is feasible under the acidic condition (9). Chromium is present in effluents released by the various industries such as metal plating, wood preserving, anodizing, ink manufacture, dyes, pigments, glass, ceramics, glues, tanning, textiles and corrosion inhibitors in cooling water.

There are various techniques which involves in the removal of heavy metal removal from the contaminated soil. But mainly two types of remediation exist for the metal-contaminated soils, 1) that leave the metal in soil by immobilizing the contaminants and minimizing their migration such as vitrification and solidification/stabilization and 2) remove the heavy metals from soil by transferring the contaminants to liquid phase by desorption and solubilization such as ex-situ soil washing and in-situ soil flushing (10, 11, 12). Research is going on to still to find out the techniques which are cost effective with volume and toxicity reduction technique (8). However some of these processes are effective only in case of single pollutants or a specific group of contaminants so the current trend is to establish a technique which can eliminate mixed pollutants from the contaminated soil. Possible solution may be the use of the combination of two or more techniques but it increases the cost of the process.

Soil washing is technique for chemical transformation of contaminants to non-hazardous materials by the physical or chemical process that results in separation, segregation and volume reduction of hazardous materials (11). Soil washing is the technique which can eliminate most of the contaminants such as metals, volatile organic compound and pesticides and herbicides in one step. So in this paper soil washing technique was studied for the removal of heavy metal from the soil.

The aim of the present study was to design a bench scale soil washing unit which could efficiently eliminate the contamination from atleast 5 kg soil at a time and to determine the most efficient wash solution and its efficiency to remove contamination from the soil by the soil washing process

## Experimental Methodology

### Soil Characterization

Sample of soil for the study was collected from the campus of Madan Mohan Malviya University of Technology, Gorakhpur. Soil sample was analyzed for different geotechnical properties. All these properties were determined according to the respective standard IS codes and summarized in table 1. Fig. 1 shows the grain size distribution curve of soil. The soil contained 47.1% sand and 52.8% silt.

Table 1: Properties of the soil

Characteristics	Test method (IS Code)	Value
Sand size content (%)	I.S: 2720 (Part 4) : 1985	47.1
Silt size content (%)	I.S: 2720 (Part 4) : 1985	52.8
Atterberg limits	I.S: 2720 (Part 5) : 1985	Non-plastic
Specific gravity G	I.S: 2720 (Part 3- Sec. 2) : 1980	2.40
MDD (g/cc)	I.S: 2720 (Part 10) : 1991	1.77
OMC (%)	I.S: 2720 (Part 6) : 1972	13.72
Permeability k (cm/sec)	I.S: 2720 (Part 10) : 1991	$3.832 \times 10^{-6}$

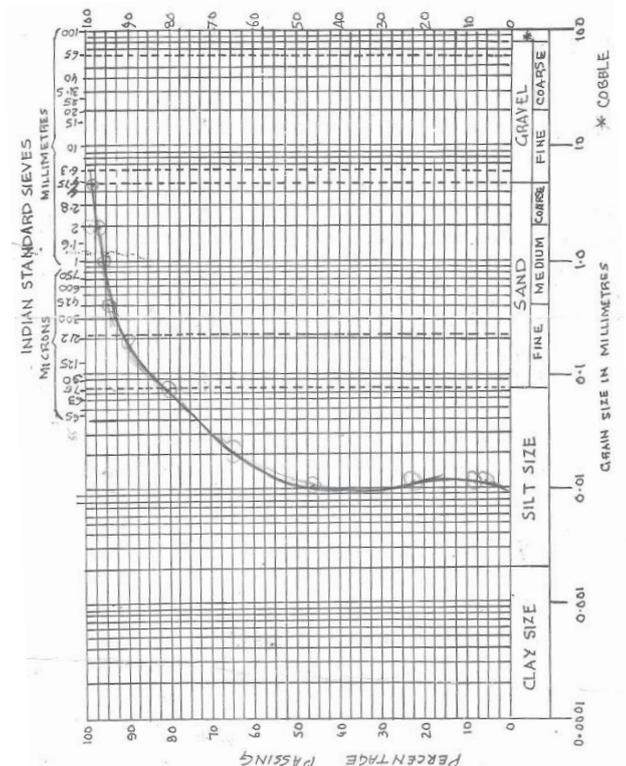


Fig 1: Soil grain size distribution

### Sample Preparation

To mimic the possible field soil contaminated condition, Soil was artificially contaminated with the known amount of the concentration of Chromium. For this, about 1 Kg of sieved air dried soil was thoroughly mixed with 3 liters deionized (DI) water containing dissolved salts of potassium dichromate ( $K_2Cr_2O_7$ ). The concentration of heavy metals was around 10000 ppm. The soil and heavy metals were thoroughly mixed with the help of hand for 7 days. At the end, mixture was air dried completely to get the constant mass.

### Bench Scale Model design

A modified bench scale setup was prepared in the Civil engineering lab of the Madan Mohan Malviya University of Technology at Gorakhpur according to the description given by the Reddy et. al., 1996 (13). This model was used to check the remedial efficiency of soil washing process to eliminate the chromium from the soil. This bench scale model can process upto 5 kg of contaminated soil at a time. This model is cost effective, simple and easy in the process operation. Fig 2 shows the picture of the bench scale model fabricated for the soil washing process.



**Fig 2: Bench scale model for the soil washing process**

The model consists of a tumbler composed of PVC material. The tumbler is 8 inch in diameter and 3 ft in length, and can be capped at both ends. The bottom cap is permanently sealed and has a PVC valve attached to it for effluent removal. The top cap is removable so that the soil and wash solution can be placed into the tumbler. A vinyl hose is connected to the top cap which allows the volatiles to escape during the machine operation. The other end of the hose is connected to a carbon filter for the safe collection of the volatiles if any.

The tumbler is placed on an inclined stand for actual operation. The stand is constructed of iron perforated angles with bolted connections. Additional tumbler support is supplied by a rotating wheel that is rigidly attached to the frame. This is driven by a variable speed AC motor. The speed variable control of the motor allows the speed of the mixing tumbler to be adjusted during operation.

### Experimental Setup and wash solution

The soil and wash solution were mixed together and placed in the rotary apparatus (Millipore) which rolled over the soil solution at the speed of 23 revolutions per minute for the different time period.  $H_2SO_4$  solution was chosen as the wash solution and different concentration and normality of the  $H_2SO_4$  solution was added in the soil. Treatment was continued upto different time intervals ranged from 1 to 24 h to check the remediation efficiency.

After the specific treatment time, the sample was removed and effluent was separated by a 5  $\mu$ m pore size pressure filter (Millipore) from the soil. The soil, in wet condition was removed from the filter paper and placed in a sample container for preservation for the further analysis.

### Testing Procedure and Analytical testing

1 kg virgin soil was mixed with the known amount of chromium in the form of potassium dichromate solution for the artificial contamination procedure. Now the 3 liters of wash solution was added in the soil. The wash solution used for this testing was the mixture of different concentrations of sulfuric acid and water. The top cap of the tumbler was then tightly closed. Tumbler size was designed in a way to accommodate atleast 5 kg of contaminated soil and 25 l of wash solution and the proper headspace to allow the volatiles to escape. The tumbler was rotated at approximately 23 revolutions per minute for approximately 24 h for the thorough interaction of the wash solution and the contaminated soil. At the end, the effluent was separated and the soil was filtered and dried. Finally the soil was to determine the final concentrations of chemical constituents. Chromium analyses were performed by using Varian AA240 flame atomic adsorption spectrometer.

### Results and discussion

Experiments were conducted with the 0.5 N, 1 N, 2.5 N and 4 N  $H_2SO_4$  solution and samples were collected at different time interval. Test results with different

normality of acid solution and treatment time is summarized in table 2. These test results were obtained by the Varian AA240 flame atomic adsorption spectrometer. From these results it can be seen that sulfuric acid solution is efficient in removing chromium contamination from the contaminated soil. As the normality of the sulfuric acid solution increase there is increase in the percentage of removal at the 24 h however initially upto 2 h there is little bit decrease was observed which may be due to the higher concentration of acid solution which slowly speed up the contamination removal process.

Table 2: Cr Removal efficiencies using  $H_2SO_4$  as washing solution at different tumbling time

Treatment time (h)	Removal Efficiency with $H_2SO_4$ solution (% Removal)			
	0.5 N	1 N	2.5 N	4 N
1	39.68	45.81	49.80	34.18
2	40.21	46.73	51.70	40.30
6	43.12	48.15	55.31	49.32
12	46.43	51.32	57.13	55.39
18	49.32	55.02	60.01	62.10
24	53.12	59.06	61.58	69.58

Fig 3 showed the Cr removal characteristics on the treatment of artificially contaminated soil with the 0.5 N  $H_2SO_4$  solution. It is observed that significant increase occurred in the removal efficiency as the treatment time increased from 1 h to 24 h. 53.12% Cr removal was observed in 24 h with the 0.5 N  $H_2SO_4$  solution addition in the soil for the soil washing process in the bench scale model.

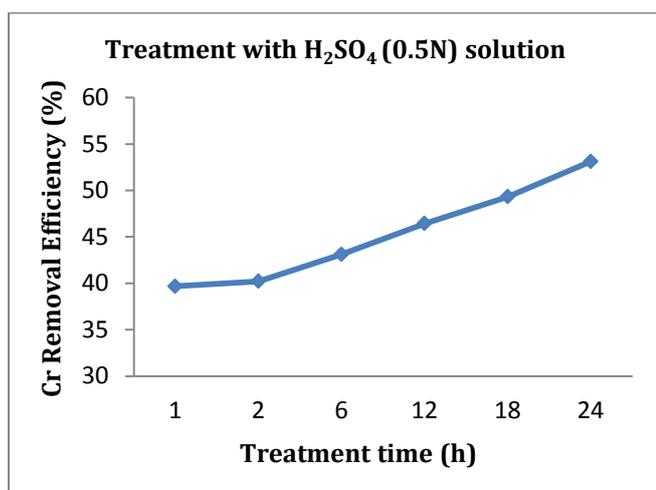


Fig 3: Cr removal using 0.5 N  $H_2SO_4$  solution as wash Solution

As shown in fig 4, it is further observed that there is increase in the Cr removal efficiency with the increase of the tumbling time with the 1 N  $H_2SO_4$  solution. 59.06% increase in removal efficiency was obtained with the use of 1 N  $H_2SO_4$  solution. From these results it is clear that both the wash solution as well as the tumbling time both affects the % removal efficiency. Thus it is important to choose the appropriate wash solution and the tumbling time to get the maximum % removal efficiency during the soil washing process. Similar results were obtained with the use of 2.5 N and 4 N  $H_2SO_4$  as washing solution to remove the Cr contamination during the soil washing process. Maximum 61.58 % and 69.58% Cr removal was obtained with the 2.5 N and 4 N  $H_2SO_4$  solution respectively as shown in fig 5 and 6. Approximately Sixty nine percent of the original soil was recovered in this bench-scale soil washing testing/technique. It is observed that as the normality of the acid solution increases there is slow increase was reported initially. After that sudden increase was observed. Slow increase in removal may be due to the high concentration of the acid solution. However in almost all the results it is observed that removal efficiency increased till 24 hr so we can continue the process till more hours but the motor used in this setup could not take extra load so we did not continued more than 24 hr. Normality of the acid solution is another factor, more than 4 N solution can also be used further but the concentration as well as cost of the overall process should also be taken under consideration.

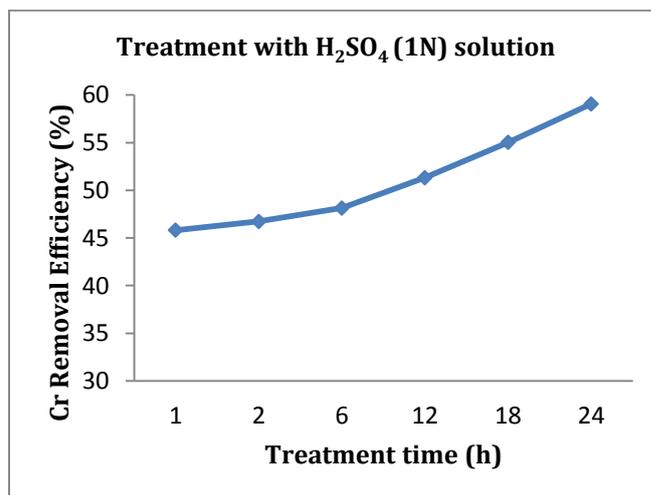
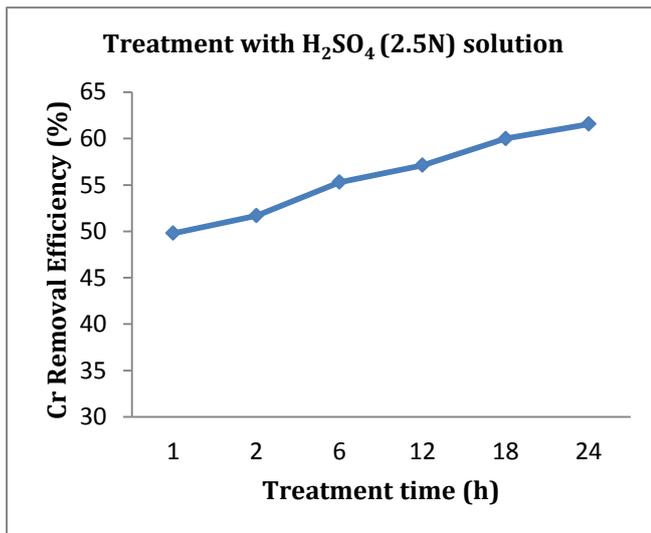
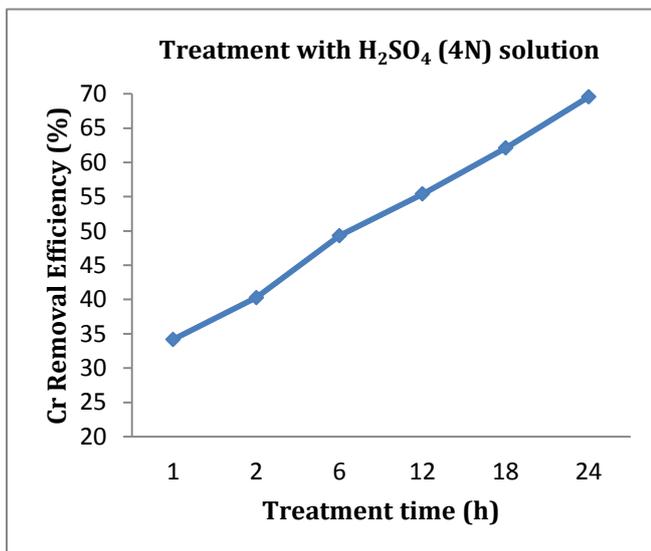


Fig 4: Cr removal using 1 N  $H_2SO_4$  solution

Fig 5: Cr removal using 2.5 N H<sub>2</sub>SO<sub>4</sub> solutionFig 6: Cr removal using 4 N H<sub>2</sub>SO<sub>4</sub> solution

As seen from all the above results, it can be easily summarized that for attaining the desired removal level from the different types of soil, both the factors i.e. choice of soil washing solution and tumbling time should be properly selected and optimised.

### Conclusion

A rotating soil washing unit/bench scale model was fabricated which was found to be efficient and effective remediation technique for the Cr removal from the contaminated soil. In this study, soil washing method was employed to remediate the soil by using H<sub>2</sub>SO<sub>4</sub> solution as the washing solution for the different tumbling time. The soil taken from the campus contained the 47.1% sand and 52.8% silt. Soil was artificially

contaminated with the potassium dichromate solution and kept in the bench scale model with the wash solution. On the basis of this study, it is clear that wash solution and soil treatment time both are the important factors for removing the heavy metal contaminants from the soil. This method is found to be simple and cost effective in nature.

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